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A PRACTICAL COMPARISON BETWEEN INTELLIGENT WATER DROP ALGORITHM & HAMILTON CYCLE IN SOLVING TRAVELLING SALESMAN PROBLEM

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Abstract

A lot of intelligent systems have been developed from nature-Inspired Optimization Algorithms which use nature event for solving problems, one of them is the rive which can find the good paths between source to destination these optimal or near optimal paths are obtained by the actions that happen among the water drops in the rivers .Hamiltonian Path in an undirected graph is a path that visits each vertex exactly once. A Hamiltonian cycle (or it's called sometimes the Hamiltonian circuit) is a Hamiltonian Path such that there is an edge (in the graph) from the last vertex to the first vertex of the Hamiltonian Path.In this paper the intelligent water drops (IWD) algorithm and the Hamilton cycle algorithm (HC) are tested to find the solution to Travelling Salesman problem (TSP) then the results are compared and shown us that HC is finding solution with guarantee 100% but with a huge complexity in term of time and space. On the other hand, IWD gives an accurate or approximated solution for solving TSP problem in linear time and space.

Keywords: Intelligent Water Drops, Travelling Salesman Problem, Hamilton cycle.

1. Introduction

Swarm-based intelligent system is one of a lot of intelligent systems that have been developed by inspiring from natural events that is related to natural swarms such as birds, ants, fishes and rivers. Some of the swarm-based techniques is an intelligent water drops (IWD).The IWD algorithm is based on the dynamic of river systems and actions that happen among the water drops in rivers, the IWD algorithm was firstly introduced in 2007 by Shah-Hosseini (Shah-Hussein ,2007). TSP is an optimization problem;which is formulated in 1930 for the first time. The main goal TSP problem is to find the shortest path of a travelling salesman who started from a city and stop by in each city exactly once and returns back to the starting city (Applegate, Bixby, Chvatal,& W. J. Cook 2007).A Hamiltonian cycle is a closed loop on a graph where every node (vertex) is visited exactly once.A loop is just an edge that joins a node to itself; so a Hamiltonian cycle is the path for traveling from a point then back to that point and visiting every node without using any edge more than once.

The rest of the paper is organized as follows. In section 2, the related work is presented. Section 3 discusses the travelling salesman problem. Section 4 and section 5 discuss the intelligent water drop, the Hamilton cycle, describe the methodology and design, and then briefly illustrates how to implement TSP by using the two algorithms. Section 6 presents the experimental results and the discussions. Section 7 concludes the paper and proposes future work for the problem.

2. Related Work

Shah Hosseini 2009 (Shah-Hosseini, 2009) suggested an algorithm based on swarm optimization inspired by nature. The algorithm gave an abstraction how to solve TSP and multiple knapsack problems by using IWD.
Shah-Hosseini in 2011 (Shah-Hosseini, 2011) proposed an IWD algorithm to solve numerical function called IWD-CO (IWD for continuous optimization). It was tested using six functions to check the satisfactory of algorithm in this area.
Noferesti & Shah-Hosseini in 2012 (Noferesti. S & Shah-Hosseini, 2012) proposed a modified IWD algorithm to solve Steiner tree problem. The goal of work was to build high quality tree in a short time that is suitable for real time routing in networks. Result showed that the superiority of modified IWD over heuristic and traditional iteration methods.
Bawaneh in 2016 (Bawaneh, 2016) constructed an intelligent framework for data hidden in grayscale image by using intelligent water drop (IWD) algorithm. The framework satisfied the system requirements as mentioned in their results.

3. Travelling Salesman Problem

The TSP is extensively studied in literature (Applegate, Bixby, Chvatal, & Cook,2007)(Grass´e,1959)(Lawler, Lenstra, Rinnooy Kan, & Shmoys,1985) and has attracted since a long time a considerable amount of research effort,the TSP is the problem of a salesman who wants to start from his home town and then finds a shortest possible trip through a given set of customer cities and to return back to its home town. More formally, it can be represented by a complete weighted graph G = (N, E) with N being the set of nodes which is represented the cities, and E the set of edges that connected the nodes N. Each edge is assigned a value dij , which is represent the length of the edge (i, j) that is represent the distance between cities i and j. For symmetric TSPs, the distances between the cities are independent of the direction of traversing the arcs, that is, dij = dji for every pair of nodes. In the more general asymmetric TSP (ATSP) at least for one pair of nodes i, j we have dij ≠dji. In this paper we will deal with symmetric where there is only one way between the two nodes.
Figure 1 shows an example of TSP problem and all the possible paths from city 1 to all other cities then shows how to select the best path of them where the cities are represented by the numbers 1 , 2 ,3 and 4 and the numbers on the edges represents the cost or the length of the edges betweenthe cities.

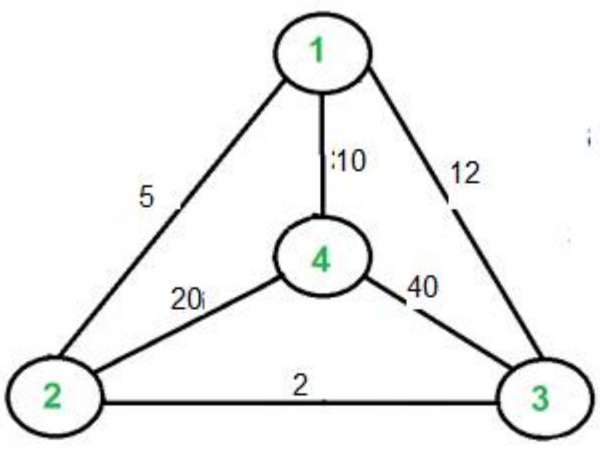

Figure 1: Sample example of TSP

Starting from city 1 all the possible paths with different costs the best one is the minimum thus path with value 44 is the best as shown in next list:

- 1 > 2 >4 >3>1 Cost of path is 5+20+40+12 =77
- 1>4 >3 >2 >1 Cost of path is 10 +40 +2 +5 = 57
- 1 >3 >2>4 >1 Cost of path is 12 + 2 + 20 + 10 = 44
- 1>2 >3 >4 >1 Cost of path is 5 + 2 +40 +10 = 57

- 1 >4 >2 >3 >1 Cost of path is 10 + 20 +2 +12 = 44
- 1 >3>4 >2 >1 Cost of path is 12 + 40 + 20 + 5 = 77

4. Intelligent Water Drop

The algorithm of IWD algorithm is based on the dynamic of river systems and what happen during dropping the water in the rivers. The IWD algorithm has two main properties: velocity and soil (Palanik kumar, D. Gowsalya, E. Rithu, B. & Anbuselven, 2012). The two properties are changed during the runtime of the algorithm. These two properties affected the path from source to destination so the increasing in the soil will decrease the speed of the river and the increasing in the velocity will increase the speed of the river so in our work we will try to decrease the amount of soil and increase the speed so that this will help us to reach to the destination in less time. Therefore, an IWD in a path with less soil becomes faster than an IWD in a path with more soil.IWD has many advantages that can be summarized by (Shah-Hosseini, 2009) It provides good quality solutions using average values, IWD algorithm has fast convergence when compared to other methods and it is also flexible in the dynamic environment and pop-up threats are easily incorporated. More ever IWD can be applied in several applications such as: Multi dimensioned Knapsack problem, Air Robot path planning, Vehicle routing problem, Travelling Salesman Problem, Texture Feature and Job Shop Scheduling. The pseudo code of IWD is shown ulterior in next steps which is illustrated in Figure 2.

Pseudo of IWD is shown in next steps which are illustrated in Figure 2.

1. Initialization of static parameters:
   - set the number of water drop N(IWD)
   - soil and velocity updating , we use parameter
     as=1000 , bs=.01,cs=1,
     av=1000,bv=.01,cv=1.
   - InitSoil, between every two node , soil(i, j)
   - Initvel;
   - Best tour TB.
2. Initialization of dynamic parameter.
   - Vc(IWD) = {}
   - Initvel,Initsoil =Zero .
3. For every IWD randomly select a city and place that IWD on the city
4. Update the visited city lists of all IWDs to include the city just visited.
5. Select next node j, provided that the node not exists in list visited nodeVc (IWD).
6. Updating its velocity when moving from node i to node j based on equation 1

   (vel)^(IWD) (t+1)=(vel) ^IWD (t)+ (a_(v))/(b_(v)+ c_(v).soil(i,j)   (1)
7. Computing mount of soil based on equation 2.

   Δsoil(i,j)= as/ (b_(s)+c_s .time([i,j;vel]^IWD)   (2)

   Which computing the time taken to moving from node i to node j based on equation 3

   →time([i,j;vel]^IWD)=‖c(i)- c(j)‖/max)ε_(v),[vel]^IWD) →ε_(V=) 1000   (3)
8. Update the soil of the path traversed based on equation 4**.**

   soil(i,j)= [(1-p).soil(i,j)-p.Δsoil(i,j)soil] ^(IWD)=[soil]^IWD+ Δsoil(i,j)   (4)
9. Repeat steps 4-8, until complete all tour, after that,computing lengthof the tour traversed by the IWD and find tour minimum length.
10. Update the soil of paths included current minimum tour of the IWD denoted by T_M, computing based on equation 5.

    soil(i,j)=(1-p)- p.[2.soil]^IWD/(N_(C) (N_(C) 1)) ∀(i,j)∈T_M   (5)
11. Update total best solution T_B, if the minimum tour T_M is shorter the T_BWe update the best tour by applying equation 6

    T_(B)=T_M and len(T_B)=len(T_M)   (6)
12. Go to step 2 unless the maximum number of iteration is reached or thedefined termination condition is satisfied.
    - Run IWD:
      - input:-
        NIWD, IWDInitsoil, initvel, linkinitsoil,
        a-v,b-v,c-v a-s,b-s,c-s [,]
        G seed file name all this variable given.
      - Output:-
        Path or tour of minimum cost

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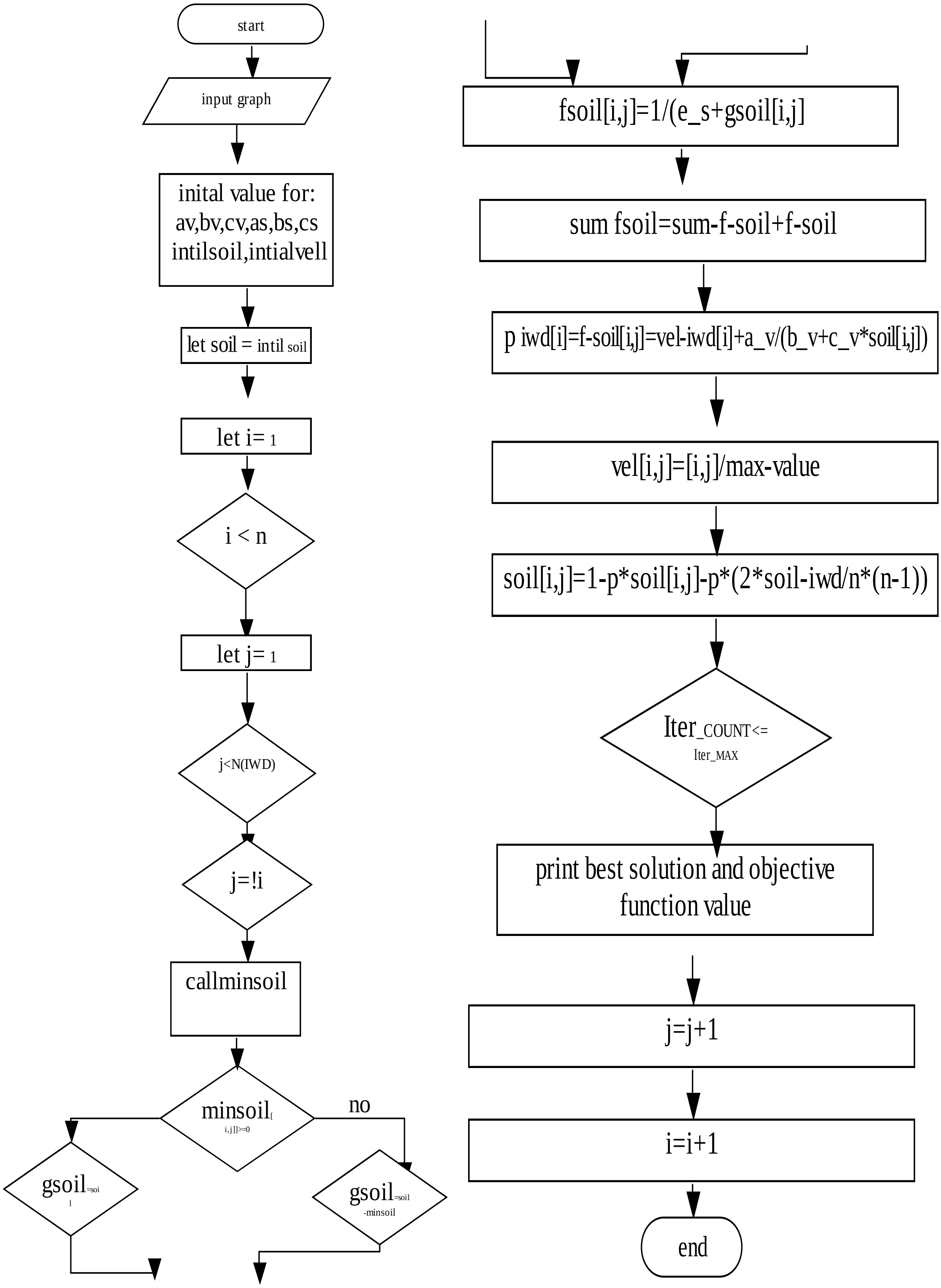

Figure 2: The flowchart for the Intelligent Water drop

5. Hamilton cycle

A Hamiltonian cycle is a graph cycle through a graph that visits each node exactly once. A graph possessing a Hamiltonian cycle is said to be a Hamiltonian graph (Grass´e, 1959)(Lawler,Lenstra,Rinnooy Kan, & Shmoys,1985) .Finding a Hamiltonian cycle in a graph is one of the classical NP-complete problems. Complexity of the Hamiltonian problem in permutation graphs has been a well-known open problem. Graph G (N, E) is designed to visit each node in N through the edge in E only once and return to the node that start from.The history of the Hamiltonian Cycle is in 1857 when Sir William Rowan Hamilton invented a puzzle-game which involved hunting for a Hamiltonian cycle. The game, called the Icosian game, was distributed as a dodecahedron graph with a hole at each vertex. Figure 3 shows pictures for Hamiltonian cycle from wolfram math world (mathworld.wolfram.com).

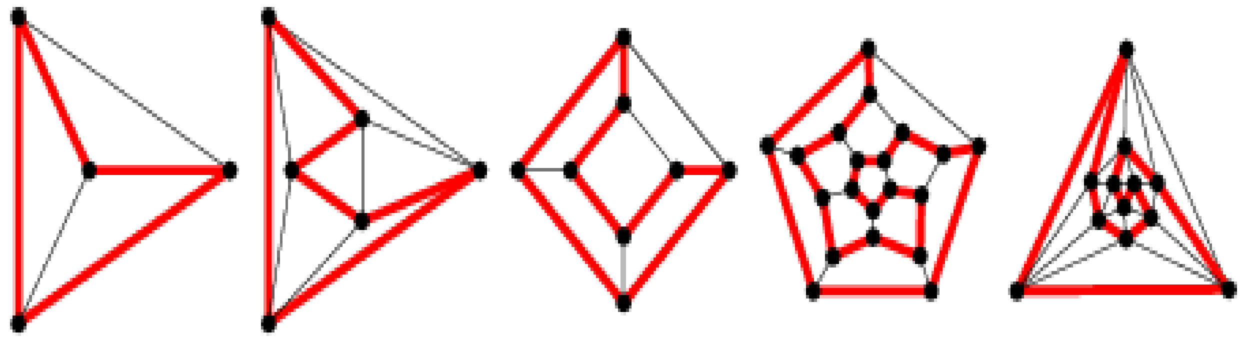

Figure 3: Hamiltonian cycle from wolfram mathworld**.**

Pseudo code Hamilton Cycle is shown in next steps which is illustrated in Figure 4.

1. Arrange the vertices arbitrarily into a cycle, ignoring adjacencies in the graph.
2. While the cycle contains two consecutive vertices vi and vi + 1 that are not adjacent in the graph, perform the following two steps: Search for an index j such that the four vertices vi, vi + 1, vj, and vj + 1 are all distinct and such that the graph contains edges from vi to vj and from vj + 1 to vi + 1 Reverse the part of the cycle between vi + 1 and vj (inclusive).
3. RUN HC:
   - Input:
     Adjacent matrix of required graph
   - output:
     Minimum path

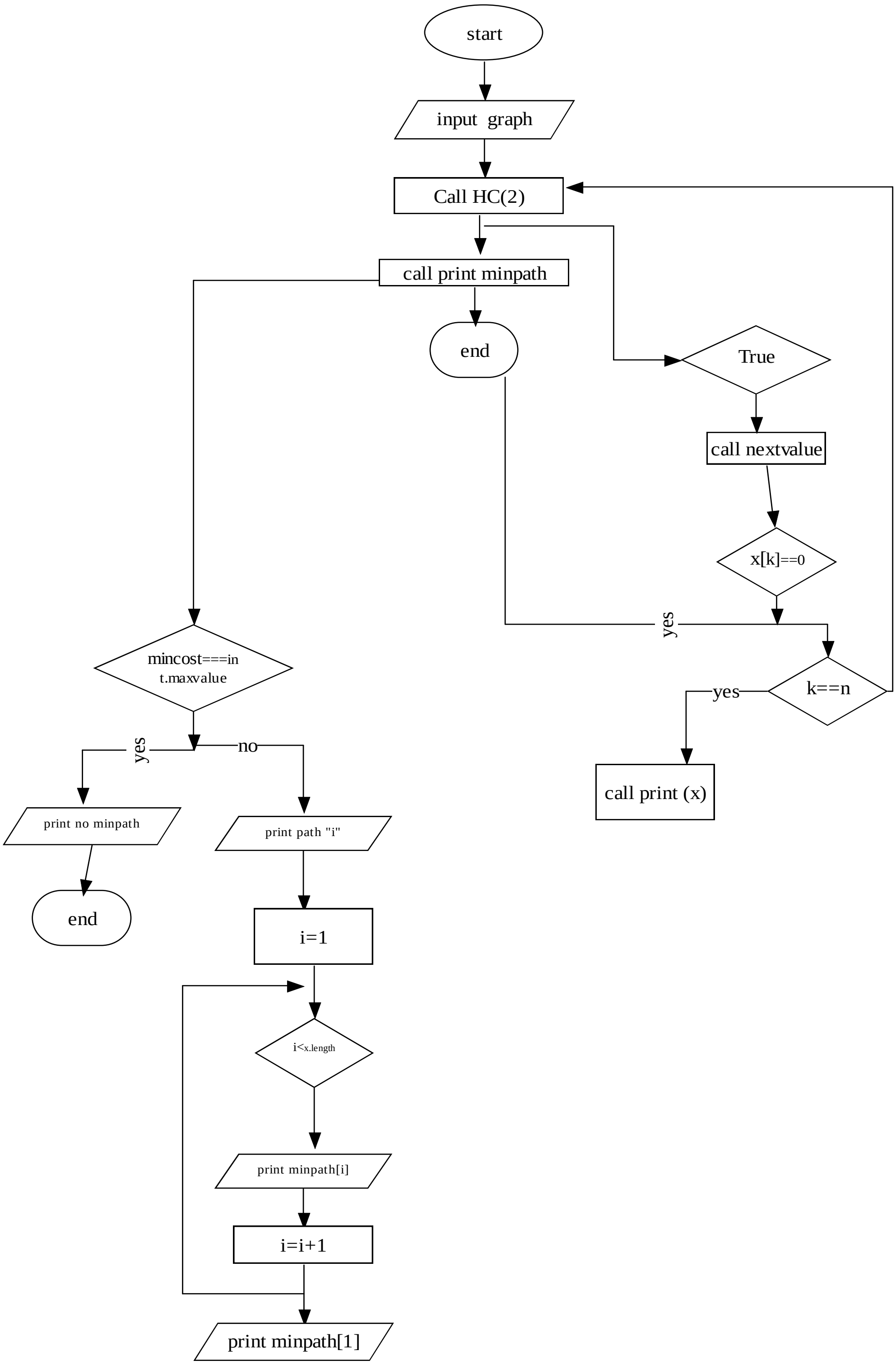

Figure 4: The flowchart for theHamilton Cycle

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6. Experimental Results

The next two figures (Figure 5 and Figure 6) show the result after running the program to find the best solution to TSP problem using IWD algorithm and HC algorithm and the results show that HC find the best solution in cost equal to 17774.59 (figure 5) and the time is equal to 0.015 ms whereas the IWD find the best solution to the same graph with cost equal to 2072.85 and the time is 0.14 ms.

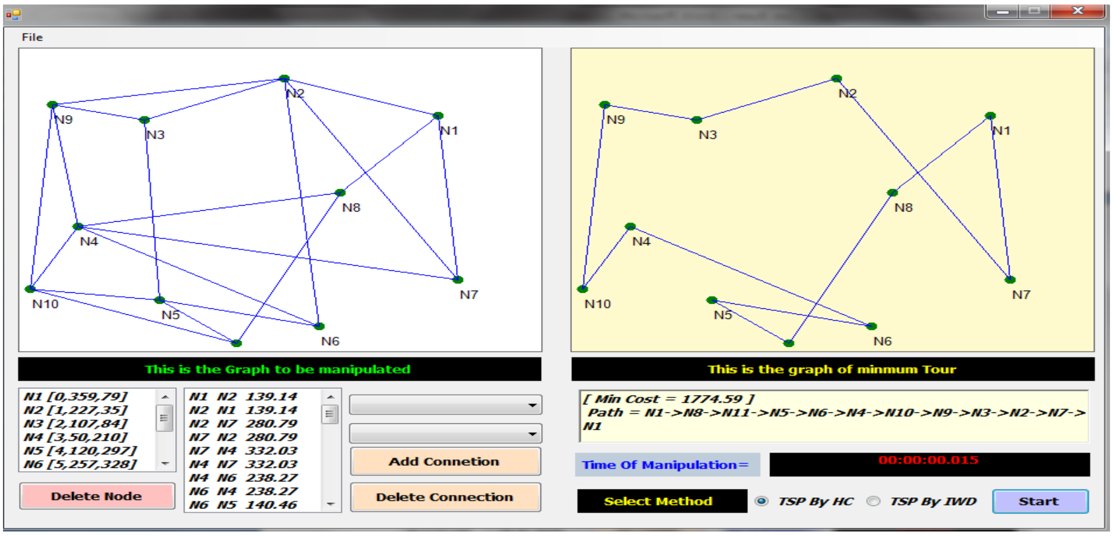

Figure 5: The solution of TSP in HC

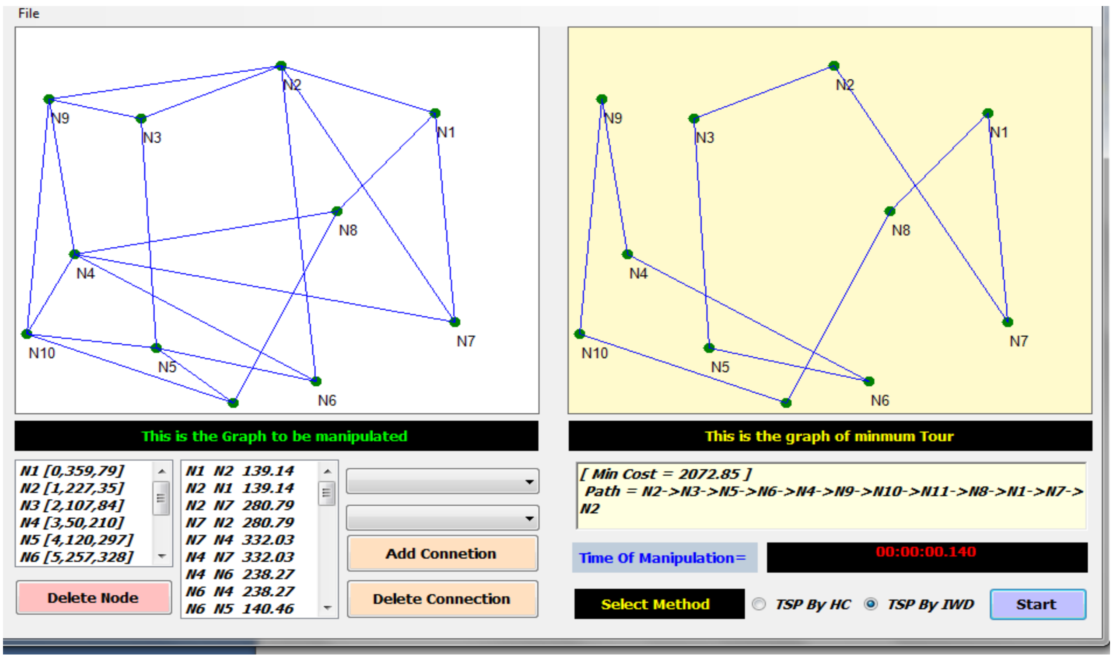

Figure 6: The solution of TSP in IWD

A lot of trials made on the program which each time show that HC is better than IWD in finding the best solution to TSP problem in less time and some of the result is written in Table 1.

Trial number	Cost for HC	Time spend in HC	Cost for IWD	Time spend in IWD
1	2040.5	0	2153.38	2,09
2	1842.66	0	2164.27	0.14
3	17774.59	0.015	2072.85	0.14
4	1907.73	0	1907.73	4.804
5	610.58	0	610.58	0.031
6	1747.86	0.014	1860.74	3.884
7	1196.55	0.015	1196.55	0.062

Table 1: The result of finding the cost and the time taken to TSP problem in HC and IWD.

Figure 7 shows the time spend in solving TSP using HC & IWD as the figure shows the HC need **less time** in solving TSP problem than IWD .

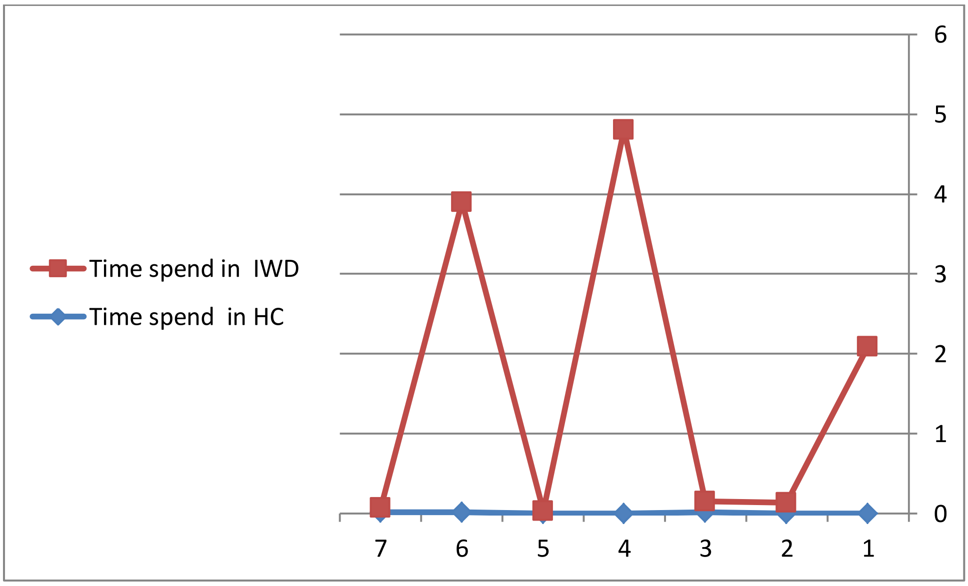

Figure 7: Time spend in solving TSP using HC & IWD

7. Conclusion and Future Work

In this paper we apply the intelligent water drops (IWD) algorithm and the Hamilton cycle algorithm (HC) algorithm to find the solution to Travelling Salesman problem (TSP) then the results are compared and show us that HC is better than an Intelligent Water Drop for solving TSP problem. The future work will examine these two algorithms on other problems.

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Biography

Sawsan Yousef Abushuqeir – I studied in Yarmouk University in Jordan and received the Bachlor's degree in computer science in 2001 and the master degree in 2004 , I work in Al balqa Applied University in Jordan since 2004 Until now I am interesting in AI and communication research .

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