Comparison of optimized Dijkstra's and enhanced Particle Swarm Optimization Algorithm to find shortest path

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***Abstract*—Swarm robotics is a new area of interest that's inspired from biological system of ants, birds and other social systems for solving different optimization problem. This paper work out to find the optimal path using particle swarm optimization algorithm and dijkstra's algorithm, these algorithms are used to find the shortest path between different nodes. Different path can exist from one node to another node, particularly combinational optimization algorithm are used to solve such optimization problem. Different algorithms are used to solve the given problem. The PSO repeatedly find out the better solution for the given problem. The dijkstra's algorithm used to check the convenience path between different nodes. Problem arise in PSO of flout delay cost at each node where the dijkstra's keep the delay cost at each node with some specific value. Our current work propose the approach to merge the PSO and Dijkstra's algorithm to provide new method of solving the optimization problem.*)*

Keywords- Dijkstra's; Particle Swarm Optimization; Optimization problem; swarm intelligence and Network Routing.

INTRODUCTION:

PSO is firstly inspired by the general artificial science, like fish schooling, bird flocking and social communication behavior of human and secondly by arbitrary search methods of evolutionary algorithm. The social organism communicate and interact with each other. Some of the properties of swarm intelligence are decentralized, self-organized system, artificial acts. In the given setup of swarm robotics individual entity combines to work together, these agents interact locally with one another and with their environment**.** Different agents communicate together and respond to the change occur in environment. The agent's communication create global intelligent behavior, and the system becomes decentralized in nature. Different swarm intelligence algorithm exists like fish schooling, bird flocking [1], bacteria growth and ant colonies [2] [3] etc.

Swarm intelligence is based upon the characteristics like no centralization, robustness and flexible system [4]. Different activity is perform in the natural swarms like construction of nest, [5] allocation of different activities, [6] path planning, [7] another individual tasks etc. [8] [9] [10].

Since the swarm robotics is mostly inspired from the nature swarms, it's a good reference for analyzing the characteristics of nature swarms. The research of swarm robotics started a century ago. The first hypothesis is quite personified [11] and assumes that each individual has a unique ID for cooperation and communication. The information exchange in the swarm is regarded as a centralized network. The queens in ant and bee colonies are supposed to be responsible for transmitting and assigning the information to each agent [12] . However, Jha, et al. [13] proved that the network in the swarm is decentralized. Thanks to the research in recent half century, the biologists can now assert that there are no unique IDs or other globally storage information in the network. No single agent can access to all the information in the network and a pacemaker is therefore inexistent. The biologists now believe that the social swarms are organized as a decentralized system distributed in the whole environment which can be described through a probabilistic model [14]. The agents in the swarm follow their own rules according to local information. The group behaviors emerge from these local rules which affect information exchange and topology structure in the swarm. The rules are also the key component to keep the whole structure to be flexible and robust even when the sophisticated behaviors are emerged.

Swarm robotics is comparatively new area that targets on governing large homogeneous simple physical robots. It is assumed that a well-combined attitude rise from the communication between robots and communication of robots with the surroundings. The path rise in the area of artificial swarm intelligence likewise biological study of insects, birds, ants and other area in the nature too, where the behavior of swarm occurs. These systems are developed and better at micro-level behaviors. These systems are made of simple and collection of small robots. Make colony and perform task collectively. It is the property of swarm robots to make population of many robots of hundreds of robots [15].

PSO is an empirical global optimization technique presented by Doctor Kennedy and E berhart in 1995. PSO is based upon two disciplines that are Computer science and social science [16]. Particle swarm optimization is new technique based on the swarm intelligence [17] [18] [19]. Different swarm intelligence models evolve some of them are fish schools, bird flocking, ant and bee colonies [11]. They search food, move in random directions. In bird flocking an individual bird having sense to find the food near to that bird. That bird contain heuristic information to find out the goal. In addition birds are sharing local information with each other, particularly better information instantaneously in search food in a specific area, the birds are inspiring from better information hence they flock toward that place where food can be found. PSO algorithm solve such problems using the same technique [20] [21].

Dijkstra's algorithm is used for solving the shortest path finding problem, while there are not a negative weight present in all edges of the graph. Similar to Prims algorithm it is greedy in nature [22] [23] and start at origin vertex O. It develop a tree Y ,that eventually store all vertices reachable to origin O. Adding vertices to the tree following order of distance, O is added first then nearest vertex to O, then the next nearest and going on.

I. LITERATURE REVIEW:

Shortest path finding is hard combinational optimization problem, different area experts work to find out the optimized path for the given problem. Various solution for such type of problem are proposed using different techniques and optimized algorithms, for example kairanbay mazghan and hajar mat jani evaluate different algorithms like Floyd warshall, genetic, dijkstra's and bellmen ford to solve the shortest path problem [24]. Their results concluded that Floyd warshall, dijkstra's give the same results, but GA algorithm give better result as compare to these two different techniques. Kavitha Sooda T. R. Gopalakrishnan Nair worked on the comparative analysis of genetic and Particle swarm optimization algorithm to find the shortest path. They show that the merit of fitness value and number of hops individually in genetic algorithm and particle swarm optimization. Moreover they illustrate that the PSO produce better solution than genetic Algorithm [25]. Praveen Sharma and Neha Khurana studied different techniques like Dijkstra's Algorithm, Genetic Algorithm, Ant Colony Optimization and Hill climbing to find out the best possible optimal path and achieve better performance in the network. Their study shows that optimization problems can be concluded better by PSO and genetic algorithm rather than traditional techniques [26]. Further the Surbhi Jawa, Rajesh Malik present the new approach of avoiding the rerouting of network if the link between the source and destination become breakout. The current work propose the better approach using particle swarm optimization. The reliable network method is followed considering the energy cost limit as low as possible for the given network. Their results indicates that the offered approach has improve the network in term of energy and reliability. The proposed algorithm proposes to deliver secure network [27]. The paper [28] introduced an enhancement of the algorithm to operate on discrete binary variables. Eberhart and shi introduced the new parameter the inertia weight into the original particle swarm optimizer to improve the results [29]. Some theory based on particle swarm optimization is also discussed by the Vora and sexena. Their work presents the small world theory based upon the given method [30]. Particularly the dijkstra's algorithm is also used in the application of human safety. The propose use of dijkstra's algorithm to find the shortest path in the critical situation like fire. This intelligence algorithm provide the secure path for the rescue operations [31]. Literature work discuss that swarm intelligence solve different hard combinational optimization problem. This approach is numerous to use in different domain like medical image segmentation. Same type of problem is discuss in paper [32] this novel approach propose the current algorithm to solve image segmentation problem. This proposed method was used in medical image segmentation and image compression with better results. In network terminology for the quality of the network, the hybrid PSO algorithm applied to improve performance [33]. Nowadays current network need to be intelligent in fact of usage reliability security and fast throughput paths.

1. PROBLEM STATEMENT:

The shortest path finding in routing is tedious task. Various nodes are interconnected and create a link as path between them. Data moves from source to destination. In this given process, the data pass through several intermediate nodes to reach destination. Different paths exist from current node. The packet moves from source to destination this scenario based upon different parameter to keep, that may be time that is to take less time to reach to destination, security of packets, moment with less consumption of energy and finding better and optimize path. The energy and time consumption, is directly related to the path followed by the packet to deliver. The reduction of time and cost depends on path selection. The selection of path is tedious job. Example (checking all possible paths) takes too much time to calculate. Achieving high performance in the network using the optimal path which selected through Routing process. Literature study elaborate that various routing problems is solved by different methods. Various path may exist between two nodes and the most optimal path is selected on the basis of associated costs, it will considered as shortest path. Different types of algorithms are used for this problem, to select the shortest path in a converged network.
In the given graph their exist a number of possible paths from start node '1' to destination node '10'.But the problem is to find optimal path, so this problem can be addressed by PSO.As starting of PSO We have to initially define particles (means initially find random path from source to destination because every particle gives solution of problem).The number of particles searching in the solution space are directly related to optimize path finding.

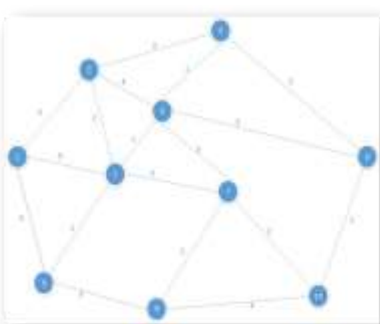


Figure1. Topology of converged network

This logic gives the algorithm provides more accurate result if particle are spread out over the network.
These initial paths break network in small search space. For example all particles are taken for this network (More number of particle give more accurate solution because more particles can cover more nodes and give more initial solution in all space). So particle value are...

$$C_{Loc}[\,][\,] = \begin{pmatrix} 125610 \\ 124610 \\ 1234610 \\ 13710 \\ 1237910 \\ 18910 \\ 1834710 \\ 1834610 \\ 134710 \end{pmatrix}$$

Here a 2D array (or matrix can also be used) matrix which show initially define particle. Since as told earlier every particles have initial velocity so velocity of particle is define by (a 2D array vector), which is initially zero.
At the starting of algorithms initial paths are the current personal best paths of particles define by (a 2D array vector). For the optimality we consider all the possible paths as Loc_Best. Next calculating the gBest from all the given nodes.

$$C_{Loc}[\,][\,] = \begin{pmatrix} 125610 \\ 124610 \\ 1234610 \\ 13710 \\ 1237910 \\ 18910 \\ 1834710 \\ 1834610 \\ 134710 \end{pmatrix}$$

And the global best is the particles which have small cost among all particles define by (a single array vector).

$$G_{Best} = [1 \;\; 3 \;\; 7 \;\; 10]$$

After initialization of particles updation is take place. Here it can be seen that difference of position gives us velocity and addition of position with velocity gives us new position. So in updation firstly velocity of particle if update by eq.1.0. Since these particles are in discrete form so updation (addition, subtraction of velocity and position) cannot be take place as normal continuous value. So this updation is defined in discrete mathematics form for example nine particle's velocity is updated as follows …

$$V_{Part}[1][] = G_{Best}[\,] - Loc_{Best}[1][\,]$$
$$V_{Part}[1][\,] = [1\ 3\ 7\ 10] - [1\ 2\ 5\ 6\ 10\ ]$$
$$V_{Part}[1][\,] = [3\ 7]$$
$$\vdots \quad = \vdots$$
$$V_{Part}[9][\,] = [1\ 3\ 7\ 10] - [1\ 8\ 3\ 4\ 7\ 10]$$
$$V_{Part}[9][\,] = [0]$$

$$V_{Part}[\,][\,] = \begin{bmatrix} 3\ 7 \\ 3\ 7 \\ 7 \\ 0 \\ 0 \\ 3\ 7 \\ 0 \\ 7 \\ 0 \end{bmatrix}$$

Every particle updates its position according to this new velocity. So updation of position of every particle is defined as

$$C_{Part} = V_{Part}[][] + C_{Part}[][]$$

For first particle we can calculate the new position as:

$$C_{Part}[1][] = [3\ 7] + [1\ 2\ 5\ 6\ 10]$$
$$C_{Part}[1][] = [1\ 2\ 3\ 5\ 6\ 7\ 10] \longrightarrow (i)$$
$$C_{Part}[2][] = [3\ 7\ ] + [1\ 2\ 4\ 6\ 10]$$
$$C_{Part}[2][] = [1\ 2\ 3\ 4\ 6\ 7\ 10] \longrightarrow (ii)$$
$$\vdots \quad = \vdots \quad \vdots$$
$$C_{Part}[8][] = [7\ ] + [1\ 8\ 3\ 4\ 6\ 10]$$
$$C_{Part}[8][] = [1\ 8\ 3\ 4\ 6\ 7\ 10]$$
$$\vdots \quad \vdots$$
$$\vdots \quad \vdots$$
$$OPT_{path} = [1\ 3\ 7\ 10] \longrightarrow (A)$$

PSO calculates the optimal path given in equation (A), provides the better possible path in solution space. Most problem arises in networking terminology for packet delivery from source to destination. Packet contains data pass through different nodes, moving from one node to another node need the connection line between those. Further if the connection is unavailable for the packet to shortest node. Now it need to find out the optimal path. PSO did not provide the clear solution for this type of problems. Moreover from equation (i) and (ii) it is clear that the set of nodes are not directly connected with each as actually that is the shortest path. The algorithm mathematically gives shortest path from source to destination. Different possible paths provide by the PSO algorithm having some uncertainties like the path which does not exists to be followed for packet movement but actually that path is the shortest path. Now this uncertainty needs to remove we need modification to solve the stated problem.

PROPOSED SOLUTION:

Swarm intelligence have a variety of techniques to solve the above mention problem. In this paper we adopted the combination of two algorithms i-e PSO and Dijkstra's. We use the discrete form to encode these algorithms. The whole search space of the problem is divided into small spaces, optimal path is find by combining all solution. It is noted that the proposed PSO-based approach can find the optimal path with good success rates and also can find closer sub-optimal paths with high certainty for all the tested networks. It is observed that the performance of the proposed algorithm surpasses those of recently reported genetic algorithm based approaches for this problem. The network topology which used in this paper is converged. Multiple paths can exist from one node to another node, needs to follow the shortest path between the nodes. The previous work is done by the researchers on this problem ignoring the delay cost. The proposed method calculate the shortest path between various nodes by using the discrete mathematics to solve this complex problem. Weighted graph topology is used to address the problem. Different techniques (dijkstra's, genetic, PSO and optimal algorithm) are used to solve the problem from different angles.

II. PSO Algorithm:

In PSO there are collection of particles named swarm which move in solution space to discover shortest path from origin to destination node [34]. Here each particle have a present location (location of particle existence in present time), local best position (best location traveled by every particle), global best location (best location of some particle among all particles in solution space), velocity (local velocity of every particle) [35]. Each particle tries to reaches the particle near to the solution in this technique [36]. Particles stop their movements after some time particularly when they reach optimal solution. The PSO is represented mathematically as follows:

$$L_i = m \times L_{i-1} + T_1 \times rand() \times (P_{best} - K_{i-1}) + T_2 \times rand() \times (G_{best} - K_{i-1}) \quad (1.0)$$

$$K_i = K_{i-1} + L_i \quad (2.0)$$

The symbols used in the above equation have the following meanings:

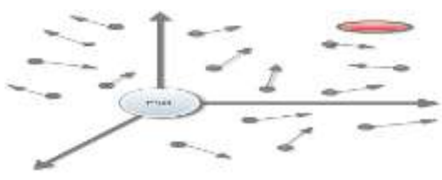
L_i -The i^{th} repetition of the particles for speed.

L_{i-1} -The speed for the current particle position (K_{i-1})

m -The inertia weight

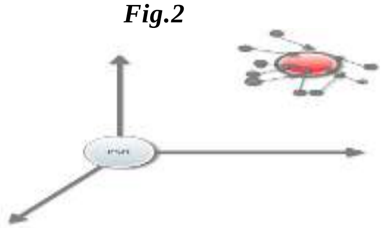
T_1, T_2 -Constant values for adjusting individual and group optimal solution

$rand()$ Random generation of numbers between 0 and 1



INITIAL SWARM PARTICLES POSITIONS

Fig.2



FINAL SWARM PARTICLES POSITIONS

Fig. 3

The above figure show that the particles initially scattered in solution space finally they reach to their goal.

General Pseudo code of PSO:

1- *Initialize swarm randomly*
2- *Repeat*
3- *For i=0 to nth iteration*
4- *Calculate the best fitness value*
5- *path availability function*
6- *Update velocity*
7- *Update best location*
8- *Update global location*
9- *Update location*
10- *End of for*

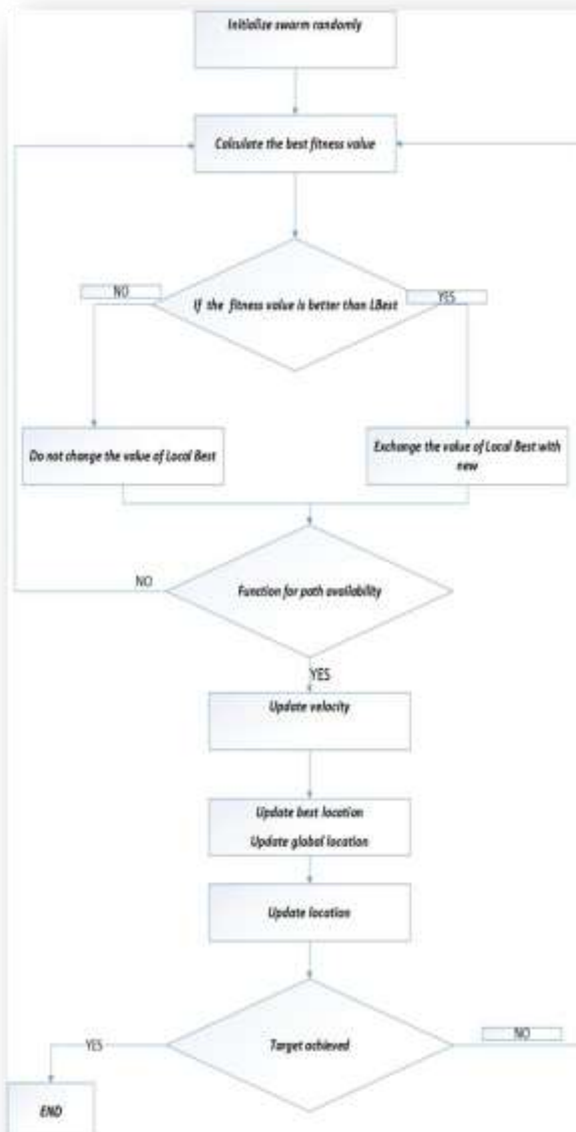
Different methods are used to address such problem like ACO, PSO, dijkstra's and Genetic algorithm. Mathematically the proposed solution will provide better results as related to other approaches. The research work proposed two different modification, such that adding learning factor to PSO, which will keep previous information of nodes. The proposed method calculate the shortest path between various nodes by using the discrete mathematics to solve this complex problem. Learning factor represented mathematically as follows:

$$Learning_{fact} = \sum_{i=1}^{n} LC \Rightarrow \begin{Bmatrix} S \\ i \end{Bmatrix}$$

$$LC(i) + LC(i+1).......LC(n)$$

$$S \Rightarrow T = A$$
$$A = B$$
$$B = T$$
$$i \Rightarrow i++$$

The LC represents the low cost of previous node and the S shows to change the nodes while i shows the number of iterations. This factor evaluates to minimize the cost of available paths. If the present nodes having different costs, it will generate the set of nodes directly connected and having low cost.



DIJKISTRA'S ALGORITHM:

Dijkstra's algorithm is used to find the shortest path from the source 'O' node to all other nodes. By developing paths in order of increasing path length. Each time adding node with next shortest path. Algorithm terminates when all nodes processed by algorithm (in set T). It is a greedy algorithm that efficiently finds shortest paths in a graph [37] . Some of the parameter is described as

N is the set of nodes in the network. O represent source node. T shows set of nodes so far incorporated by the algorithm. W(i,j) is the cost from node i to node j. L(n) represent the least cost path from node O to node n that is currently known to the algorithm [24].

Delay components:

Nodal processing delay*:* The time that a node takes for the processing of a packet. It include time for reading packet header, checking, suitable link to the next node and error checking.

Queuing delay*:* Time taken by packet at a node until other packets are not transmitted. In general the queue delay is presented as: dqueue = dtrans*length_queue

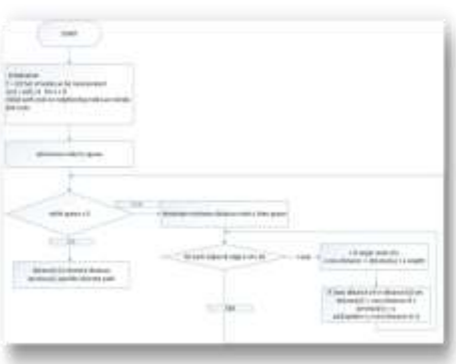
***Transmission delay*:** Getting whole packets "out of door". Let packet have L bits and transmission rate of a link is Rb/s. So transmission delay is L/R.

***Propagation delay*:** Time required for a bit to pass through medium among two switches [38] [39].

Dijkstra's algorithm mathematical model:

The shortest path problem is an issue consisting in finding the shortest connection between vertices in the weighted graph. There is a directed graph G (V, E), Where V denotes the set of vertices, E is the set of edges connecting vertices.

The weighted function $w = E \rightarrow R$ is assigning real-valued weights to the edges – the weights can be interpreted as costs to traverse the edges.



$$P = (v_0, v_1, v_2 \ldots v_n) \qquad \rightarrow \qquad (1)$$

The total cost of a path is defined by (2)

$$C(p) = \sum_{i=1}^{n} w(v_{1-i}, v_i) X_1, \ldots, X_n \qquad \rightarrow (2)$$

The cost of the shortest path from u to v can be expressed in the form given by (3):

$$\mu(u,v) = \begin{cases} \min\{C(p) : u \xrightarrow{p} v,\} \\ \infty \end{cases} \qquad \rightarrow \qquad (3)$$

The above equation defines the µ value if the path exist from u to v, otherwise the solution goes to infinite (∞) The shortest path from u to v is the path p, whereas path between the nodes exists if the following condition is satisfied as defined (4):

$$C(p) = \mu(u,v) \qquad \rightarrow (4)$$

In the shortest route case, the weighted function is defined as the sum of the distances between successive intersections on the route. The total cost can be described by (2) in which, where $w(v_{i-1}, v_i) = d(v_{i-1}, v_i)$ is the distance between the intersection of u and v, i.e. by (5)

$$C(p) = \sum_{i=1}^{n} d(v_{1-i}, v_i) \qquad \rightarrow \qquad (5)$$

In the shortest route case, the weighted function is defined as the sum of ratios of the distances between successive intersections and the speed limits on the road between them. The total cost can be described by (6), where s (u, v) describes speed limit from u to v**.**

$$C(p) = \sum_{i=1}^{n} \frac{d(v_{1-i}, v_i)}{s(v_{i-1}, v_i)} \qquad \rightarrow (6)$$

1) **5.3.** Pseudo code for optimized Dijkstra's algorithm:

1. [Initialization]
   a. T = {O} Set of nodes so far incorporated
   b. L(n) = w(O, n) for n ≠ O
   c. Initial path costs to neighboring nodes are simply link costs
2. [Get Next Node]
   a. find neighboring node not in T with least-cost path from O
   b. incorporate node into T
   c. also incorporate the edge that is incident on that node and a node in T that contributes to the path
3. [Update Least-Cost Paths]
   a. L(n) = min[L(n), L(x) + w(x, n)] for all n ≠ T

b. if latter term is minimum, path from O to n is path from O to x concatenated with edge from x to n

4. [CALCULATE NODE COST]

a. A. COST (NEW-NODE) = COST (PREV-NODE) + DTRAN + DQUEU + DP

5. CONCLUSION:

This paper present an approach to solve the shortest path problem using PSO and dijkstra's algorithm. But presented approach addressed shortest path problem in a different way. The updation in PSO remove the uncertainty in general PSO approach. Moreover merging PSO and dijkstra's produces satisfactory results. Furthermore considering nodal delay in dijkstra's algorithm gives results free of ambiguities up to large extent or up to extreme limit. The proposed method is used to solve the multi cost routing problems. The traffic problem is also solved by the proposed method. The proposed method focus to minimize the cost, selecting of reliable link, replacing of down links by new and shortest links. Moreover paper concludes that metahuristic knowledge provides the chance to select better and optimal path. The calculation of distance for the next root updating period, totally based on metahuristic knowledge. Moreover the link costs are decided on the base of particular router parameter (e.g. delay, queue length, node of cost, and length of link).

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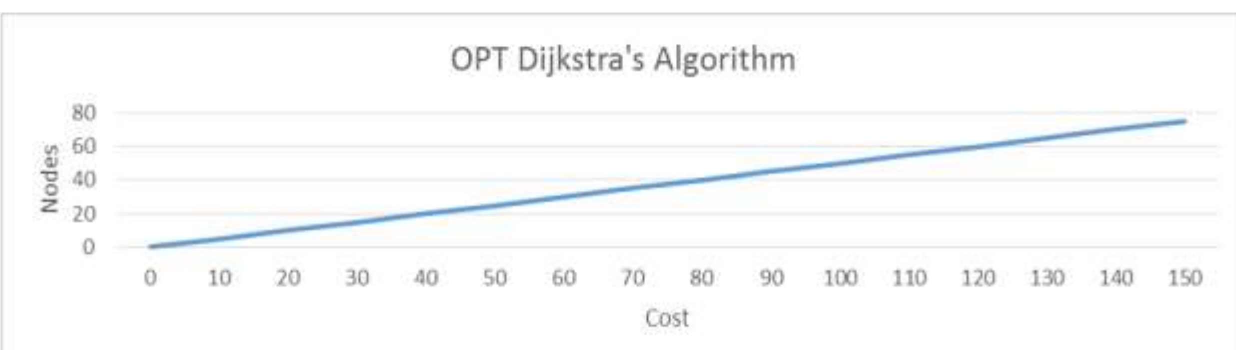


Enhace PSO
Cost
60
40
20
0
5
10
15
20
25
30
Particles