(1) Project idea in details

❖ the idea of project is Vehicle routing problem. VRP is an important problem in both the field of distribution and logistics, since at least the early 1960s. This project is about applying an ACO (Ant Colony Optimization) algorithm to solve the Vehicle Steering Problem (VRP).

-The description of the problem of vehicle routing (VRP) states that m vehicles originally situated in a depot are to deliver n different quantities of goods to n customers.

-The solution of the VRP is a set of routes which all begin and end in the depot, and which satisfies the constraint that all the customers are served only once.

-The goal (VRP)is to determine the optimal breaker so that it can be used by vehicles when serving a group of users, i.e., the goal is to reduce the total transportation cost.

- The transportation cost can be improved by reducing the total travelled distance and by reducing the number of the required vehicles.

-In this project, an algorithm based on **swarm intelligence** will be applied to the VRP.

★We will discuss the swarm intelligence algorithm:

-Definition of swarm intelligence:

swarm intelligence deals with natural and artificial systems that composed of many individuals .is a technique based on collective behaviors that result from the interaction between agents and environment. Agents can be (Ants, Birds, Individuals, Fish). Swarm Intelligence use the decentralized control and self-organization.

first introduced by Gerardo Beni and Jing Wang in 1989 with their study of cellular robotic system.

Examples of Swarm in natural

-Swarm of Bee

agent: ants

- Flock of Birds

agents: Birds

- Crowd

agents: Humans

- Traffic

agents: Cars

-Immune system

agent: Cells, Molecules

Advantages of Swarm Intelligence

1) The systems are flexible because can add or remove agent without influencing structure.

2) The system can adapt to new situations .

Disadvantages of Swarm Intelligence

Uncontrollable, because the system it is very difficult to exercise control over swarm.

We will discuss the vehicle routing problem in detail:

-The vehicle routing problem (VRP) is an extension to the problem of the travelling salesman problem (TSP) because in this problem the seller travels to many of cities,

where it leaves and returns to the point of origin again, so the (VRP) is like the (TSP) where one or more vehicles exit to deliver many separate goods to many users, but the customer must be visited only once by one vehicle.

-The aim of the VRP is to find the vehicle routing(s) with minimum cost or else, in other words, finding a minimum distance or cost for the roads that several vehicles use to serve a certain number of customers.

Mathematically

the VRP system can represented by a weighted graph G= (V, A, D).

1- where the nodes or vertices represented are by V = {V0, V1, ..., Vt}, where the nodes represent customers on the graph.

2- the actions or arcs can represent by the A= {(vi, Vt): I ≠ t}, it is considered the link or path between vehicles and customers.

3- While the distance between vehicles and customers is represented by d, it is either the (travel cost or travel time) between Vi and Vt.

The VRP is solved by some constraints:

1- customer should be visited only once, in one vehicle.

2- Each vehicle must start and end its route at the point of origin (depot), v0.

3- Each vehicle must not exceed the specified lane length.

★the purpose of VRP

1- Minimize the range and costs related with vehicle use.

2- Reducing the number of vehicles to serve several customers.

3- Reducing unacceptable services by users, such as delaying delivery of goods.

4- Balancing roads in terms of travel time and load of vehicles.

To obtain the shortest path between the vehicle and the customers, an algorithm called an ant colony optimization algorithm is used, where simulates the way ants reach the food source with the least path.

★We will discuss the ant colony optimization algorithm (ACO):

-Definition of ACO:

-in 1992, the scientist Macro Dorigo proposed the ant colony optimization algorithm (ACO), which is an algorithm that simulates ants, and its main purpose is to find the shortest path by using graphs and search for good solution to the optimization problem.

-It is desired to send some packages to different destinations, the computer must calculate the shortest route for each package to reach its destination, the computations will be very large and will cost a lot.

-If there is new route that is shorter than the first route, the computer must calculate the routes again.

- ACO is a set of software agent called (artificial ants).

-ACO can be used to finding the solution to the difficult optimization problems.

-the artificial ants build the solution by moving on the graph by

using a set of parameters associated with graph components.

(nodes or edges) the value of parameters changed at runtime by ants.

- ACO helps to find a solution for this with simple mathematical procedure.

❖How to determine the shortest path through ants?

- The behavior of ants is random.

-Scientists have found that ants communicate with each other to tell each other the shortest route from their home to the food.

Ants emits a chemical substance called pheromones, where the trails of pheromones allow them to find short
- paths between their nests and sources of food.

- while walking the route with a high density of pheromones is the shortest path as it is the most frequent route visited by ants.

-on the other hand, the route with a low density of pheromones is a less frequently used route and by the time the pheromones evaporate, and no ants walk in this route.

- To solve VRP, this function of real ant colonies is exploited in ACO algorithms.

- the pheromone trails are modified in two ways, firstly ants build a round, they change the local pheromone ratio on the edges, Secondly, after the ants built their tour, the pheromone update process is applied to the edges that belong to the best round that was found.

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(2) Main functionalities

1) Find the nearest depot for every customer.

2) Divide number of given vehicles over the number of depots.

3) Show the shortest found path for each vehicle in the depot which have the minimum cost during the iteration.

4) Divide number of vehicles for each depot to the number of the nearest customer for this depot.

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(3) Similar applications in the market

◆One of the major success stories of operations science is known to be vehicle routing. There have been hundreds of active implementations in scores of sectors in various nations over the last 40 years. Since 1950, The successful implementation of the vehicle orientation program has helped the emergence of accurate and complex geographic information systems technology and. use the VRP in many applications such as **Geographic Information Systems for Transportation (GIS-T), Courier Service, E-grocery delivery** and **travelling salesman**, **to achieve the same goal of vehicle routing.**

1-Travelling salesman:

The Travelling salesman problem is the same as the vehicle Routing problem and is solved by using the ant colony optimization algorithm.

The Travelling salesman problem (TSP) has been an important problem in the field of distribution and logistics. TSP It is a problem to find the shortest tour by visiting all cities in a certain group of cities.

The purpose of the traveling salesman problem is the same as the purpose of the vehicle Routing Problem which is to reduce the overall transportation cost.

Where it is possible to improve the cost in the problem of the (VRP) by reducing the number of vehicles required and reducing the total distances traveled and, also improving the cost in the problem of (TSP) by reducing the The total transportation distance traveled between cities. cost can be reduced by reducing the total distance traveled from one city to another.

The TSP can solve under a few constraints as follows:

3) Each city is visited only once.

2) a salesman must start and end its route at the start point.

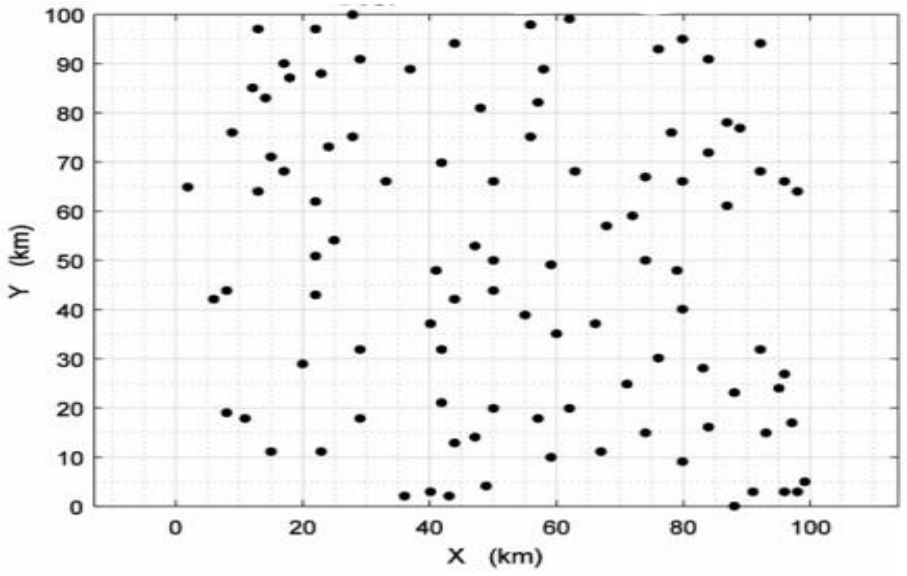
for example, if a salesman starting from his home city is to visit each city exactly once and then return home.

3) salesman must not exceed the length of the specified path to reach a specific town.

mathematically

the system of TSP can represent as a weighted graph G= (V, A, D) where the nodes or vertices represented are by V = {V0, V1, … ….., Vt}, where the nodes represents cities on the graph and the actions or arcs can represented by the A, it is considered the link between cities or the path, While the distance between cities is represented by d, it is either the (travel cost or travel time that the salesman) consumes during his tour.

In finally the TSP represented using a graph and the cities can represented as nodes on the graph.



2-courier service

-The problem of the courier service is to get the shortest way to deliver (packages) mails to a group of customers, but by using VRP, which is the optimal solution that was found using many algorithms, including the ant colony optimization algorithm, but the VRP is divided into many types, which are ,VRP with time window (VRPTW),Dynamic (DVRP), Stochastic (SVRP), Capacitated (CVRP) and many other types, but the result was found that the types of VRP used for the courier service is VRPTW or DVRP, or they can be combined together.

-Where time Window VRP is used to find a specific delivery time that the courier should not skip.

-The courier service must be fast and accurate in the process by using the shortest route and low cost because this improves the quality of the courier service. as the transportation cost is reduced by reducing the process time and reducing the variable cost or fixed cost. Examples of variable costs are (employee salaries, maintenance, and fuel costs).

-variable costs are more influential to the degree of overall transportation costs than their fixed costs.

General purpose of using VRP in a mailman service app:

1-Find the shortest path.

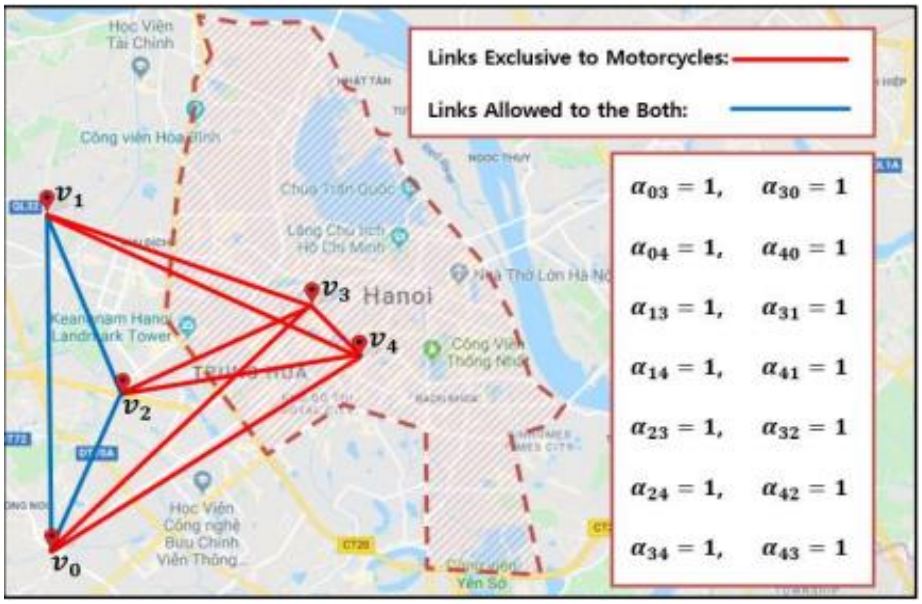
2-Meet the needs of users at the lowest cost.

3-Reduce services that are less satisfactory to consumers, such as late delivery times for mail or documents.

Courier services are companies that offer packages or documents to a group of customers, as the most important aspect that separates courier services and regular postal delivery is the speed and efficiency of delivery.

Benefits of courier service:

The advantages associated with the use of courier services are numerous Secure deliveries of parcels, Reasonable rates, packaging, and package monitoring.



3- E-grocery delivery

-The e-grocery delivery routing problem is considered a group of supermarkets that provide services to the homes of Internet shoppers.

-Shopping operations through the Internet take place in two forms: The first type is that companies contain stores and fulfill online customer orders in the traditional way, but the second type is that companies own these stores in addition to external vendors that contain goods that are not available in the company's stores.

EDRP depend on distribution network, that consist of:

1) a depot → is a store or depot of online grocery that provide the standard products.

2) vendors → external vendors or external shops that provide premium products that not available at the depot.

3)Regular customers → that buy only standard products.

4)Premium customers → that order standard and premium products.

-**Routing regular** customers is considered a special case directly from EDRP represented in the form (VRP), where a specific order is requested for a product that is in the depot, then only one vehicle is directed to the customer and then returns to the same starting point, which is the depot.

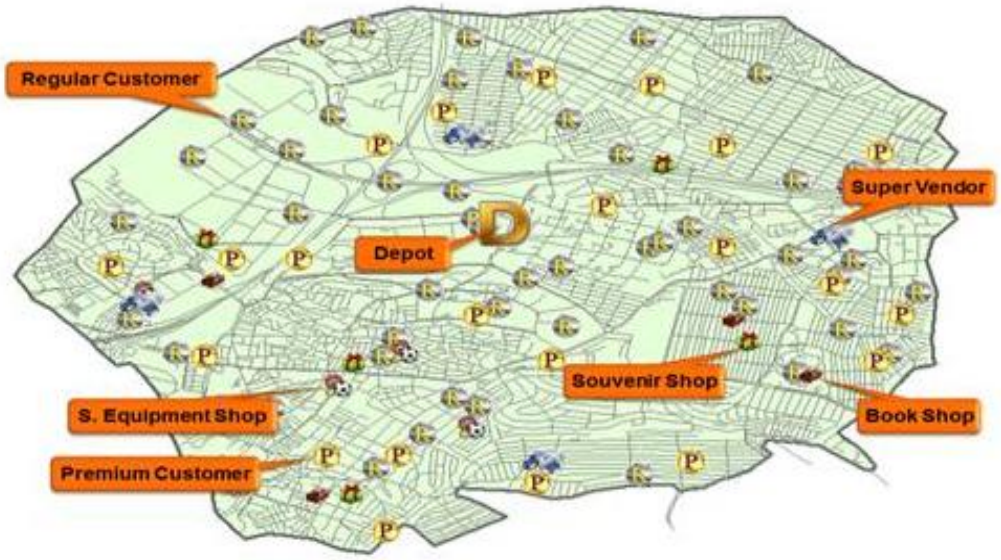
-**But routing premium** customers by allocating a seller for each customer to meet the premium products (outside the depot) where all the distinguished products are purchased and then we combine them with the required standard products and then they are delivered to the customer and then return to the starting point which is the depot.

-routing regular customers and premium customers and their respective vendor but while maintaining viability concerns such as precedence, vehicle capacity, and time windows.

-EDRP does not allow the delivery of goods to distinguished customers except after collecting the

distinguished products and combining them with the products required from the depot.

-EDRP does not allow vehicles to roam during the goods delivery process as the products are delivered through a short distance (short path) and this happens through capacity constraints and time window.



4-Geographic Information Systems for Transportation (GIS-T)

Introduction about GIS:

- (GIS) It provides an opportunity for users by combining or compiling spatial information from a group of different sources into one framework. Geographic information systems also use to find accurate spatial measurements, such as calculating road distance from the user's location to the nearest place he wants to reach (hospital, supermarket, or any other place).

-Geographic information systems can be a computer software, a group of computers, or a distributed service or

can be accessed via the Internet, a system, or a tool. It is used to store, process, analyze data, present geographically as maps, and allow the user to create searches.

GIS has many applications:

1) Transportation

2) Analysis

3) Planning

4) construction.

4.1) Geographic Information Systems for Transportation (GIS-T):

-geographic information systems for Transportation are interconnected systems of data, devices, people, and programs to be able to collect and publish information to many the regions and analyze it.

-The aim of geographic information systems for transportation is to analyze data and carefully manage transport databases and know how to address networks to solve the basic routing problem.

-GIS-T encompasses a wide variety of transport and logistics, such as preparation and maintenance of infrastructure, study of travel demand, traffic tracking and regulation, public transit planning.

-Minimum cost routes and flows through spatial networks are main GIS-T, subjects for reasons at the intersection of computation and geography.

But the GIS for transportation depends on publishing or transmitting information to many areas through the shortest path. Therefore, the Dykstra algorithm was used, then the GIS followed the approach or rules for the vehicle routing problem and the travelling salesman to get the shortest path and the lowest possible cost.

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(4) An initial literature review of Academic publications

https://www.researchgate.net/profile/Firoz_Mahmud2/publication/329505854_A_Novel_Three-Phase_Approach_for_Solving_Multi-Depot_Vehicle_Routing_Problem_with_Stochastic_Demand/links/5c0bb3e54585157ac1b17c0b/A-Novel-Three-Phase-Approach-for-Solving-Multi-Depot-Vehicle-Routing-Problem-with-Stochastic-Demand.pdf

(5) the Dataset employed

-Dataset description

http://neumann.hec.ca/chairedistributique/data/README.TXT

-Dataset

http://neumann.hec.ca/chairedistributique/data/mdvrp/old/

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(6) Details of the algorithm

★Analysis of ACO

- The ACO is influenced by ant colonies' ageing habits.

- In this algorithm, indirect communication takes place between the ants to find the optimal path, which is the shortest path until they can reach the food source.

- In the ACO algorithm, this characteristic of real ant colonies is used to address discrete optimization problems.

-The shortest way is found by concentrating the pheromones ratio on the edges of the path, this indicates the concentration of ants also, on this path, which makes it the best path to reach their food source.

★Algorithmic design

✓ Suppose we have a single source, a single ant colony, and 2 possible paths to traverse.

✓ We can represent this problem with a weighted graph, where the vertices of the graph are the ant colony and food source, the paths are the edges, and the pheromones values are the weights on edges.

✓ Let the graph be G = (V, E) where V, E are the edges and the vertices of the graph.•Vs is the source vertex (ant colony).

✓ Vd is the destination source (food).

✓ There are 2 edges E1, E2 with Lengths L1, L2 respectively.

✓ The values of pheromones on edges are R1, R2 for E1, and E2 respectively.

✓ For each ant, the starting probability to select a path.

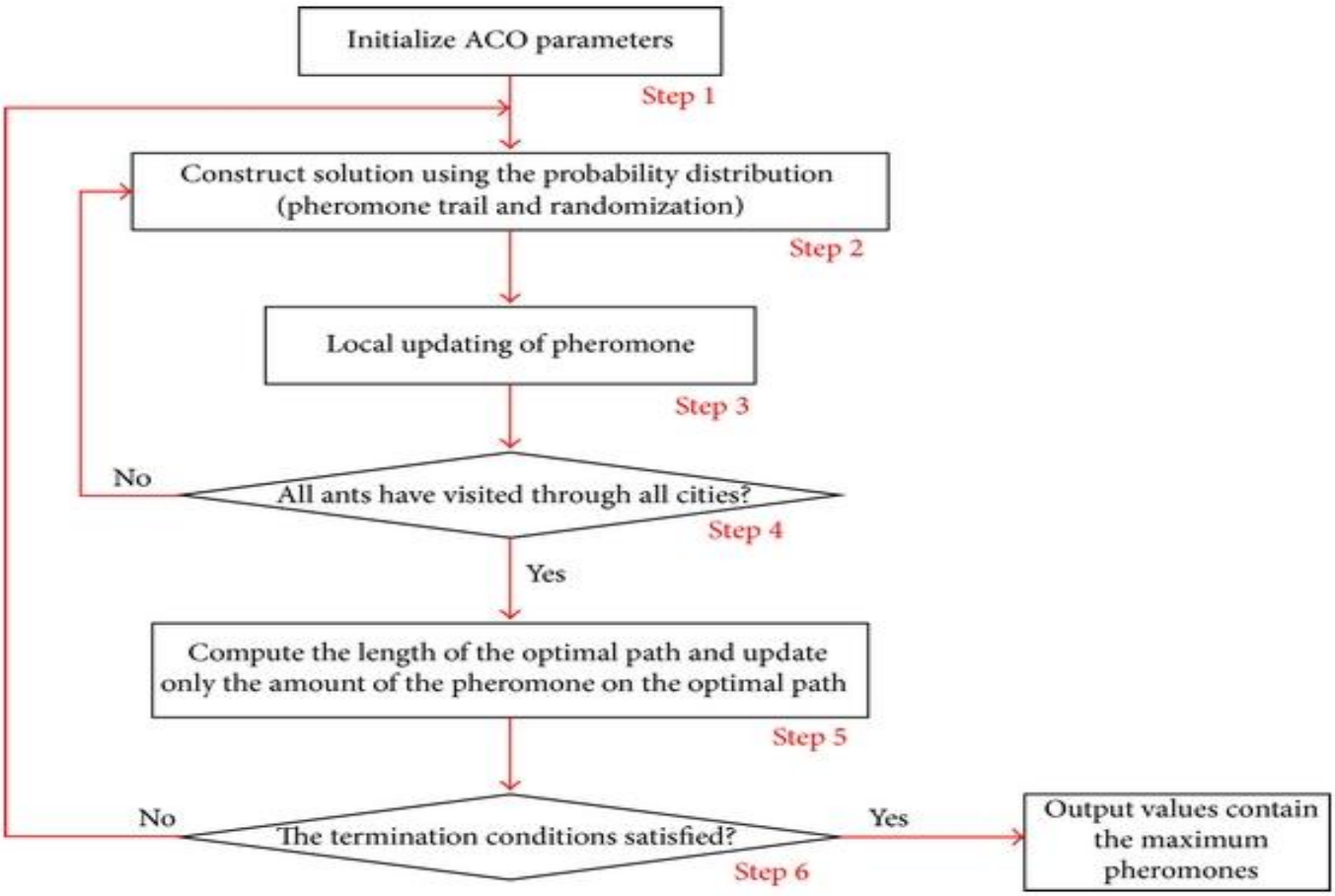
$$Pi = \frac{Ri}{R1 + R2} \; ; i = 1,2$$

✓If probability of R2>R1 this means that the probability of choosing E2 is higher and vice-versa. Pheromones values in the path used to return will be updated, the update is done based on the length of the paths and the evaporation rate of pheromones.

1-According to path length $Ri \leftarrow Ri + \frac{K}{Li}$ "k is a parameter of the model".

2-According to evaporation rate $Ri \leftarrow (1 - v) * Ri$

★Flow chart of ACO algorithm



★Pseudo-code Algorithm for ACO:

Initialization

While termination condition not met do:

AntBasedSolutionConstruction ()

PheromoneUpdate ()

Daemonactions ()

End while

✓ First step consists mainly of the initialization of the pheromone.

✓ Then stating the loop while termination condition not met do.

✓ then procedure AntBasedSolutionConstruction ()

✓ Pseudo-code of AntBasedSolutionConstruction ()

- s = <>
- Determine N(s)
- While N(s) != 0 do
  - c←chooseFrom(N(s))
  - s←extend s by appending solution component c
  - Determine N(s)
- End While

AntBasedSolutionConstruction ():

The finite set of components of solution
-c={c1,c2,c3,…cn}

is derived from the discrete problem of optimization under consideration.

Solution construction starts with an empty sequence s
-=<>

then, the current sequence s is at each construction step extended by adding a feasible solution component from the set N(s) ⊆ c.

-The choice of a solution component from N(s) is at each construction step preformed probabilistically with respect to the pheromone model.

PheromoneUpdate ():

-In the update of the pheromone values they add, various ACO variants primarily differ.

-We will outline a general pheromone update rule.

- The update rule consists of two parts.

-First part a pheromone evaporation is needed to avoid rapid convergence of the algorithm toward a sub-optimal region.

-The second one used to increase the value of pheromone trail parameters on solution components.

DaemonActions ():

-Daemon actions can be used to implement centralized actions which cannot be performed by single ant. Examples are the application of local search methods to the constructed solutions, or the collection of global information that can be used to decide whether it is useful or not to deposit additional pheromone to bias the search process from a non-local perspective.

★Advantages of ACO algorithm

1) Effective for traveling salesman problem and related issues .

2) May be used for dynamic software (adapts to changes such as new distances).

3) Positive feedback leads to the fast exploration of good solutions.

★Disadvantages of ACO algorithm

1) Difficult in theoretical analysis.

2) Research should be experiential, not theoretical.

3) Decision sequences are not independent but rather random.

★ Applications of ACO algorithm

1) portfolio optimization.

2) train scheduling.

3) Group-shop scheduling problem.

4) Bioinformatics problems.

5) Industrial problems.

6) Data mining.

7) Quadratic assignment problem.

8) Continuous optimization.

9) Graph coloring.

10) cell placement problems arising in circuit design.

★ the results of the experiments

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Process finished with exit code 0
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(7) Development platform:

the libraries that used in this project are:

1- pandas

2- math

3- numpty

★**cross-platform python**
