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Quadrative Assignment Problems (QAP) using Ant Colony Optimization (ACO)

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Abstract
During the last few decades, the human beings desire efficient and effective optimization of problems. This paper discussed the optimization of quadrative assignment problem. Ant colony optimization is used in this paper for better outcome. The paper is based on the development of a mathematical model to tackle the problems of allocation of distributors and wholesalers/retailers. Simulation is done on 15 distributors and 15 wholesalers/retailers and a matrix of 15 x 15 has been prepared for the distances between them. The GUI is designed for the Assignment Problem using MATLAB. The article covers both situations of Assignment Problem i.e. Maximization or Minimization. In this paper, the simulation has been done on data based of Laxmi Plywood, Yamuna Nagar.

I. INTRODUCTION

Global competition in the organizations is changing very rapid and quickly. For the effective results in any field the demand of optimization has risen to a great extent. Everyone around be it a scholar or researcher is finding out the best possible way to optimize the problems related to their fields.

The Quadratic Assignment Problem was originally used to model a location problem in 1950. Even then it was computationally very difficult to solve which make it an ideal candidate for research work. The Quadratic Assignment Problem (QAP) is a standard problem in location theory. It was introduced by Koopmans and Beckmann in 1957 and is a model for many practical problems. Intuitively, the QAP can be described as the problem of assigning a set of facilities to a set of locations with given distances between the locations and given flows between the facilities. The goal then is to place the facilities on locations in such a way that the sum of the product between flows and distances is minimal.

II. SWARM INTELLIGENCE

A novel approach of Artificial Intelligence (AI) is Swarm Intelligence, which is inspired by real world insects. There comes a lot of swarms under this category the social insects such as ants, termites, bees, and wasps and by swarming, flocking, herding, and shoaling phenomena in vertebrates. Swarm Intelligence (SI) is recently invented High Performance Technique for Optimization which is objective of all the Engineering application. Beni & Wang introduced the expression “Swarm Intelligence” in 1989, in the context of cellular robotic systems. Swarm Intelligence, one of the most recent sub fields of Artificial Life, can be defined as any attempt to design algorithms or distributed problem-solving devices inspired by the collective behavior of social insect colonies and other animal societies. Swarm intelligence is an innovative computational and behavioral metaphor for solving distributed problems that originally took its inspiration from the biological. While nature remains a fundamental source of inspiration for researchers in swarm intelligence, new ideas originating from the most different areas in engineering and computer science are emerging and strongly influencing the field. Despite this continuous evolving of the swarm intelligence definition, key principles such as self-organization, distributions, parallelism, and exploitation of local communication mechanisms among relatively simple individuals are emerging as invariants of this innovative computational and behavioral metaphor. Examples of systems like this can be found abundant in nature, including ant colonies, bird flocking, animal herding, honey bees, bacteria, and many more. SI models have many features in common with Evolutionary Algorithms (EA). Like EA, SI models are population-based. The system is initialized with a population of individuals (i.e., potential solutions). These individuals are then manipulated over many generations by ways of mimicking social behaviors of insects or animals, in an effort to find the optima. Unlike EA, SI models do not use evolutionary operators such as crossover and mutation. A potential solution simply "flies" through the search space by modifying itself according to its relationship with other individuals in the population and the environment.

The most successful swarm intelligence techniques currently in existence are Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO). ACO is a metaheuristic optimization algorithm that can be used to find approximate solutions to difficult combinatorial optimization problems. The Ant System is a general-purpose heuristic algorithm, which can be used to solve diverse combinatorial optimization problems. This work has been lead by Marco Dorigo at the Politecnico di Milano. Ant algorithm is multi agent system in which the behavior of the each single agent is called artificial ant, is inspired by the behaviour of real ants. Ant Colony Optimization (ACO) is a paradigm for designing metaheuristic algorithms for combinatorial optimization problems. PSO is a global minimization technique for dealing with problems in which a best solution can be represented as a point or surface in an *n*-dimensional space. Commander (2005) discussed the Quadratic Assignment Problem (QAP) as one of the most interesting and most challenging combinatorial optimization problems in existence. Grosan (2009) introduced a nature inspired meta-heuristic for scheduling jobs on computational grids. In this paper, Section III provides brief introduction to Ant colony optimization. Laxmi Plywood data are used to verify the proposed method and simulation results of experiments are illustrated in Section VI. The conclusion and future scope are presented in end of this paper.

III. ANT COLONY OPTIMIZATION

An perceptive description of the foraging behavior of ants is shown in figure 1. Initially, three ants leave their nest in random directions to search for food. As they wander around, they deposit certain amount of pheromone trails, which will evaporate slowly but are detectable by other ants.

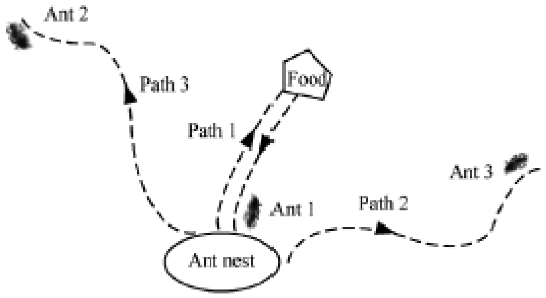

Fig. 1: Foraging behavior of ants.

Let us assume *Ant* 1 finds a food source. It will pick up some food and return to the nest by following its own pheromone trail, laying additional pheromone on the same path while *Ant*2 and *Ant* 3 are still wandering randomly. When the next group of ants leaves their nest to search for food, they detect twice as much pheromone on *Path* 1 than on *Path* 2 and *Path* 3, assuming the evaporation of pheromone is negligible. Since the probability for a path to be followed is proportional to its pheromones value, more ants will follow *Path* 1 in this second round of search for food. In this way, the ants can establish the optimized path from their colony to the feeding sources.

Ant Colony Optimization (ACO) is a paradigm for designing metaheuristic algorithms used for combinatorial optimization problems. Ant Colony Optimization is a metaheuristic in which a colony of artificial ants cooperates in finding good solution to difficult discrete optimization problems. ACO algorithms have the following desirable characteristics:-

1. It is versatile.
2. It is robust and general purpose.
3. It is a population-based heuristic.

The artificial ant colonies will have some major differences with a real (natural) one:

- Artificial ants have some memory.
- They are not completely blind.
- They live in an environment where time is discrete.

ACO algorithms can be used to solve both static and dynamic combinatorial optimization problems. Static problems are those in which the characteristics of the problem are given once and for all when the problem is defined and don't changes while the problem are solved. A paradigmatic example for such problem is Traveling salesman problem (TSP) (Dorigo and Gambardella, 1997). On the contrary, dynamic problems are defined as a function of some quantities whose value is set by the dynamics of an underlying system. The problem instance changes therefore at run time and algorithm must be capable of adapting on line to change environment. An example of this situation is network routing problems.

In a relaxed way, an ACO algorithm can be imagined as the interplay of three procedures: Construct Ants Solutions, Update Pheromones, and Daemon Actions. **Construct Ants Solutions** manages a colony of ants that concurrently and asynchronously visit adjacent states of the considered problem by moving through neighbor nodes of the problem's construction graph *G*. **Update Pheromones** is the process by which the pheromone trails are modified. The trails value can either increase, as ants deposit pheromone on the components of connections they use, or decrease, due to pheromone evaporation. Finally, **the Daemon Actions** procedure is used to implement centralized actions which cannot be performed by single ants.

IV. PROBLEM FORMULATION

This paper is based on the development of a mathematical model to tackle the problems of allocation of distributors and wholesalers/retailers in an optimized way so as to make the distributors more streamlined to avoid any haphazard created due to wrong allocations and maximize salesmen profits. Laxmi Plywood is constantly facing this problem which in turn consumes lot of valuable manpower and management's precious time due to improper allocation because of non-availability of any such system in the Laxmi Plywood. Laxmi Plywood has number of distributors in New Delhi/Delhi who are supplying different categories of papers to different wholesalers/retailers.

The procedure has been carried on 15 distributors and 15 wholesalers/retailers. A matrix of 15 x 15 has been prepared for the distances between them.

V. METHODOLOGY

Precisely, assignment model can be given as:

$$x_{ij} = \begin{cases} 0, \textit{if the ith facility is not assigned to jth job,} \\ 1, \textit{if the ith facility is assigned to jth job.} \end{cases}$$

Then, the model is given by

$$\text{minimize } Z = \sum_{j=1}^{n} \sum_{i=1}^{n} C_{ij} \left\{ = \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} C_{ij} \right\},$$

subject to constraints

$$\sum_{j=1}^{n} x_{ij} = 1,\ i = 1,2,3,......., n,$$

$$\sum_{i=1}^{n} x_{ij} = 1,\ i = 1,2,3,......., n,$$

and x_{ij} = 0 or 1.

If the last condition is replaced by $x_{ij} \geq 0$, the transportation model with all requirements and available resources will be equal to 1. The methodology is illustrated in flow chart shown below in fig. 2:

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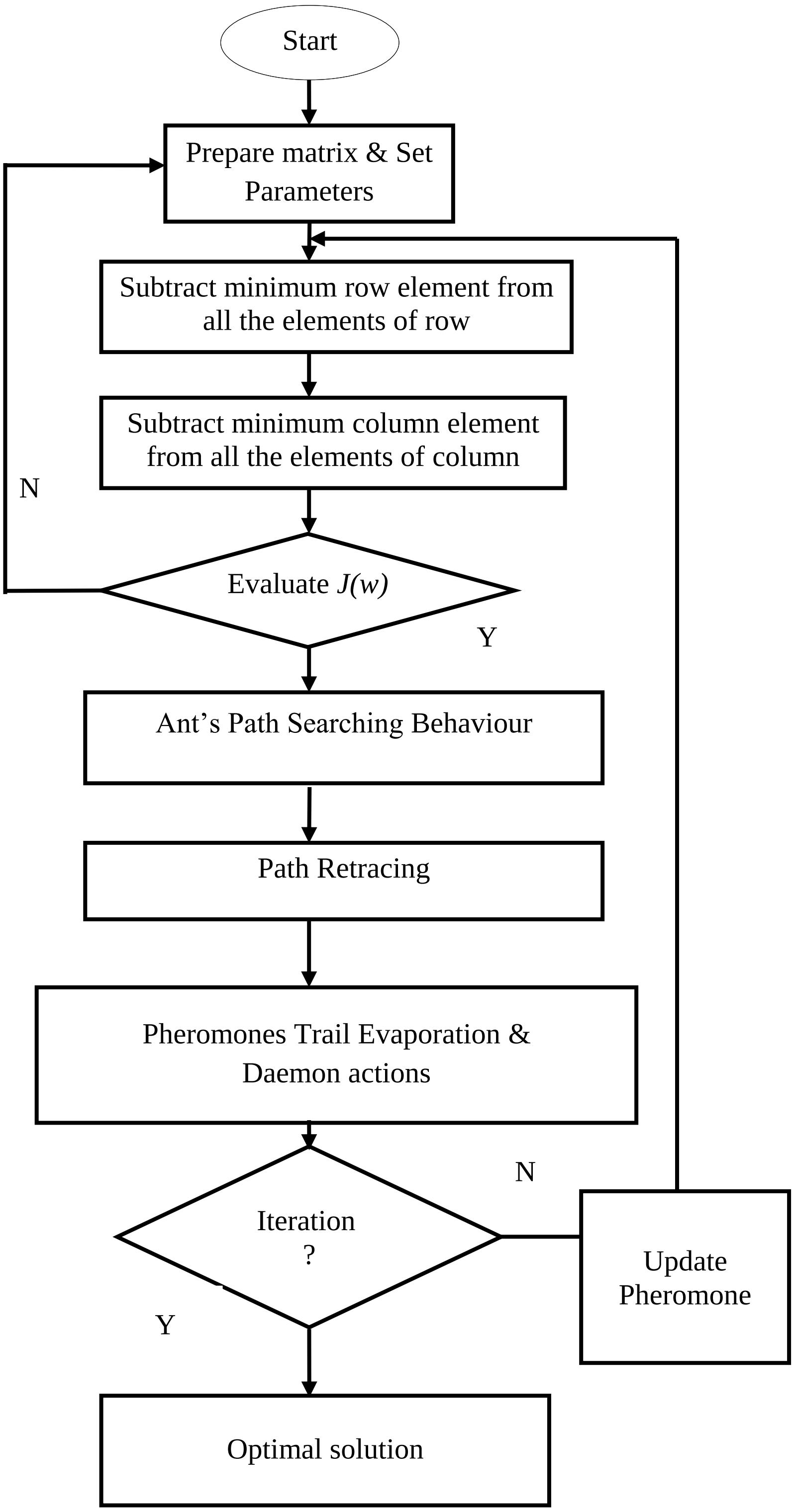

Fig. 2: Flow Chart of Algorithm

VI. RESULTS

Graphical User Interface (GUI) has been prepared using MATLAB. The Screen shot of the same is shown below in figure 3.

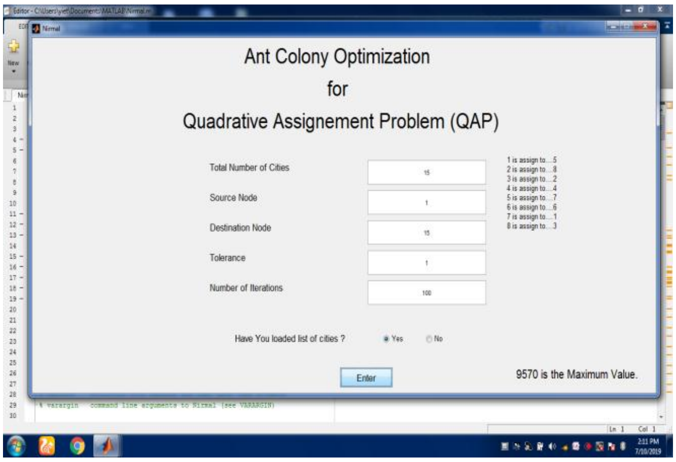

Fig. 3: Screenshot of GUI designed

VII. CONCLUSION

GUI is designed for the Problem mentioned above. There are two situations in Assignment Problem i.e. Maximization or Minimization. The simulation is done for Laxmi Plywood for 15 distributors and 15 retailers. In the minimization problem, the minimum distance from collected data comes out to be 681 Km. The algorithm assigned the best suitable retailer to each distributor because this will minimize the distance by 20 % as compared to the distance taken from random movement.

In the maximization problem, the maximum profit of data retrieved from company turns out to be Rs. 7500. The algorithm assigned the best suitable location to each salesman to achieve the maximum possible profit giving 10% hike as compared to the average profit.

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