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Chapter II

Intelligent Ant Colony System for Traveling Salesman Problem and Clustering

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Abstract

Processes that simulate natural phenomena have successfully been applied to a number of problems for which no simple mathematical solution is known or is practicable. Such meta-heuristic algorithms include genetic algorithms, particle swarm optimization, and ant colony systems and have received increasing attention in recent years. This work parallelizes the ant colony systems and introduces the communication strategies so as to reduce the computation time and reach the better solution for the traveling salesman problem. We also extend ant colony systems and discuss a novel data clustering process using constrained ant colony optimization (CACO). The CACO algorithm extends the ant colony optimization algorithm by accommodating a quadratic distance metric, the sum of K nearest neighbor distances (SKNND) metric, constrained addition of pheromone, and a shrinking range strategy to improve data clustering. We show that the CACO algorithm can resolve the problems of clusters with arbitrary shapes, clusters with outliers, and bridges between clusters.

History of Ant System and Ant Colony System

The Ant System algorithm (Colorni, Dorigo, & Maniezzo, 1991; Dorigo, Maniezzo, & Colorni, 1996) is a cooperative population-based search algorithm inspired by the behaviour of real ants. As each ant constructs a route from nest to food by stochastically following the quantities of pheromone level, the intensity of laying pheromone will bias the path-choosing decision-make of subsequent ants. It is a new member of the class of meta-heuristics joining algorithms such as simulated annealing (Kirkpatrick, Gelatt,, & Vecchi, 1983; Huang, Pan, Lu, Sun, & Hang, 2001), genetic algorithms (Goldberg, 1989; Pan, McInnes, & Jack, 1995), tabu search approaches (Golver, & Laguna, 1997; Pan, & Chu, 1996), particle swarm optimization (Eberhart, & Kennedy, 1995; Chang, Chu, Roddick,, & Pan, 2005] and neural networks (Kohonen, 1995; Kung, 1993). In common with many of these, the ant system algorithm is similarly derived from nature.

The operation of ant systems can be illustrated by the classical traveling salesman problem (see Figure 1). In the TSP problem, a traveling salesman problem is looking for a route which covers all cities with minimal total distance. Suppose there are n cities and m ants. The entire algorithm starts with initial pheromone intensity set to τ_0 on all edges. In every subsequent ant system cycle, or episode, each ant begins its trip from a randomly selected starting city and is required to visit every city exactly once (a Hamiltonian circuit). The experience gained in this phase is then used to update the pheromone intensity on all edges.

Given a finite set of cities and the distance between each pair of cities, the traveling salesman problem (TSP) aims to find a route through all cities by visiting each exactly once and returning to the initial city such that the total distance traveled is minimized. Assume m artificial ants travel through n cities. The operation of ant systems for the traveling salesman problem (*TSP*) is given next (Dorigo, Maniezzo, & Colorni, 1996; Dorigo & Gambardella, 1997):

Step 1: Randomly select the initial city for each ant. The initial pheromone level between any two cities is set to be a small positive constant. Set the cycle counter to be 0.

Step 2: Calculate the transition probability from city r to city s for the kth ant as:

$$P_k(r,s) = \begin{cases} \sum_{u \in J_k(r)} \frac{[\tau(r,s)] \cdot [\eta(r,s)]^\beta}{[\tau(r,u)] \cdot [\eta(r,u)]^\beta} & , \quad if \quad s \in J_k(r) \\ 0 & , \quad otherwise \end{cases} \tag{1}$$

where r is the current city, s is the next city, $\tau(r, s)$ is the pheromone level between city r and city s, $\eta(r,s) = \frac{1}{\delta(r,s)}$ the inverse of the distance $\delta(r, s)$ between city r and city s, $J_k(r)$is the set of cities that remain to be visited by the kth ant positioned on city r, and β is a parameter which determines the relative importance of pheromone level versus distance. Select the next visited city s for the kth ant with the probability $P_k(r, s)$. Repeat step 2 for each ant until the ants have toured all cities.

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