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Scatter Search with ACO for Load Balancing In Structured P2P Systems

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Abstract

For effective working of peer to peer systems the load balancing is the critical task. To assign the load to a particular node, care should be taken that cost incur to assign the load should be minimized. The problem consists of a number of tasks that are to be assigned to various nodes in the network at the least cost. In this paper we describe an algorithm for load assignment where other approaches resort to randomization.

An analogy with the way ant colonies function has suggested the definition of a new computational paradigm, which we call *Ant System*. It is a viable new approach to stochastic combinatorial optimization. The main characteristics of this model are to the nodes in the network that is inspired by scatter search using ant heuristics. Scatter search contrasts with other evolutionary procedures, such as genetic algorithms, by providing unifying principles for joining solutions based on generalized path constructions in Euclidean space and by utilizing strategic designs.

Keywords:- Load balance, Scatter search, structured peer to peer networks, reference set.

1. INTRODUCTION

The central idea of scatter search (SS), first introduced by Glover [2], is to keep a small population of reference solutions, known as reference set, and combining them to form new solutions. Reference set is created by first generating a large number of solutions using a diversification generation method.[2]. The solutions to be put in reference set (rs) are selected by taking into account both their solution quality and their diversity.

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Then the solutions in rs are used to build subsets of solutions. The solutions in each subset are combined . This process is repeated until reference set does not change any more. The approach was motivated by the supposition that information about the relative desirability of alternative choices is captured in different forms by different rules, and this information can be exploited more effectively when integrated by means of a combination mechanism than when treated by the standard strategy of selecting different rules one at a time, in isolation from each other. In addition, the method departed from the customary approach of stopping upon reaching a local optimum, and instead continued to vary the parameters that determined the combined rules, as a basis for producing additional trial solutions.

To summarize various steps of SS are:-

1. A *Diversification Generation Method* to generate a collection of diverse trial solutions, using an arbitrary trial solution (or seed solution) as an input.

2. An *Improvement Method* to transform a trial solution into one or more enhanced trial solutions. (Neither the input nor the output solutions are required to be feasible, though the output solutions will more usually be expected to be so. If no improvement of the input trial solution results, the "enhanced" solution is considered to be the same as the input solution.)

3. A *Reference Set Update Method* to build and maintain a *reference set* consisting of the *b* "best" solutions found (where the value of *b* is typically small, e.g., no more than 20), organized to provide efficient accessing by other parts of the method. Solutions gain membership to the reference set according to their quality or their diversity.

4. A *Subset Generation Method* to operate on the reference set, to produce a subset of its solutions as a basis for creating combined solutions.

5. A *Solution Combination Method* to transform a given subset of solutions produced by the Subset Generation Method into one or more combined solution vectors.

The algorithm that is discussed in the next section uses Ant heuristic systems[3][5] for generating the reference set. The heuristic used have the following properties:

- *Population based* approach. This is interesting because it allows the exploitation of positive feedback as a search mechanism, as explained later in the paper. It also makes the system amenable to parallel implementations .
- *Versatile*, in that it can be applied to similar versions of the same problem.
- *Robust*. It can be applied with only minimal changes to other combinatorial optimization problems such as the quadratic assignment problem (QAP) and the job-shop scheduling problem (JSP).

These desirable properties are counter balanced by the fact that, for some applications, the Ant System can be outperformed by more specialized algorithms. This is a problem shared by other popular approaches like simulated annealing (SA), and tabu search (TS), with which is used for comparing the Ant System.
The algorithm that is defined in the next section is derived from the study of real ant colonies. The major use of artificial ant colonies and real ant colonies are:-

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

Then at last the best solution is picked from the reference set generated by the ants. Ants have the property that they move randomly in various directions in search of food. They lay down some quantity of an aromatic substance, known as pheromone, on their way to food and on their way back to the nest. Ants choose to follow a pheromone trail with a probability proportional to the pheromone trail intensity.

2. PROBLEM STATEMENT

We will perform a searching technique called scatter search to search the node that have the capacity of taking the load.[4]
Let *I* is the set of tasks (i=1,..., n) sorted in decreasing order ; *J* is the set of nodes (j=1,..., m) ; *bj* = resource capacity of node *j* ; *aij* = resource needed if task *i* is assigned to node *j*; *cij* = cost of task *i* if assigned to node *j* . The variables are: *xij* = 1, if task *i* is assigned to node *j*; 0, otherwise. Assume that

$$a_{ij} \le b_j \quad \text{and} \quad \sum_{i=1}^{n} a_{ij} > b_j$$

(1) min $$f(x) = \sum_{j=1}^{m}\sum_{i=1}^{n} c_{ij} x_{ij} \qquad [1]$$

s.t.

(2) $$\sum_{i=1}^{n} a_{ij} x_{ij} \le b_j, \quad j = 1,\ldots\ldots,m$$

(3) $$\sum_{j=1}^{m} x_{ij} = 1, \quad i = 1,\ldots\ldots,n$$

(4) $$x_{ij} \in \{0,1\}, \quad i = 1,\ldots\ldots,n \;;\; j = 1,\ldots\ldots,m$$

3. PROPOSED ALGORITHM

The algorithm we propose is inspired by scatter search which basically performs three steps. First, a reference set is generated using ant heuristics which consist of all feasible solutions. Second the pheromone on all the paths explored by the ants for the feasible node is updated. Last, the best solution is chosen from the reference set
ASH is an instance of the Ant Colony Optimization approach. The input parameters are the pheromone trail variable τ_{ij} , denoting the intensity of the desire to assign task i to node j. Initially all ants will be placed on the overloaded node and pheromone trail τ_{ij} is inversely proportional to the cost of assigning the task i to node j.

$$\text{i.e. } \tau_{ij} = \frac{1}{c_{ij}}$$

where c_{ij} is cost incurred if task i is assigned to node j.
Let i be the task for which reference set is to be created:

- Ants will move on all the directly connected paths with probability p_0 in search of food i.e. node with sufficient capacity and maximal value of τ_{ij} .
- With probability1-p_0, ants will move towards the node with sufficient residual capacity according the following probability function:

$$p_{ij} = \frac{\tau_{ij}}{\sum_{j' \in J} \tau_{ij'}}, \forall j \in J \quad (1)$$

- The nodes selected by the ants are the members of the reference set.
- Then the optimal node is chosen from the reference set and the pheromone τ_{ij} for that node will be updated if and only if the node has capacity left for any of the waiting tasks after absorbing the current task.

The parameter p_0 controls the degree of exploitation and exploration of an ant. Exploitation causes the system to make use of its current achievement, whereas exploration forces the system find a new and better solution. The tradeoff between exploration and exploitation is a key issue of an ant system. The ant exploits the path with a maximal value of τ_{ij} with probability p_0; otherwise, it explores other paths according to (1). With a high value of p_0, the best possible choice is made most often. If the probability p_0 =1, the ant will always choose the best possible path and will not perform any exploration. The probability p_0 must be designed to balance exploitation and exploration. The definition of probability p_0 in our algorithm is defined to be p_0=((|I|-|J|)/|I|)x0.8.[9]. The above first two steps constitute the first step of the scatter search algorithm.

Ants will move in various directions in search of food (node that have sufficient capacity) and keep on updating the reference set which constitutes the third step of scatter search where every element of the reference set is the feasible solution for the task i. This iteration will be repeated till there is no more updation in the reference set.

The forth step is to make the subsets of the reference set. The subsets of the reference set containing not more than n elements are then created. Each subset will be analyzed for absorbing tasks other than i. The subsets that satisfy this condition are also combined in the reference set which constitutes the last step of scatter search.

From the reference set created by scatter search the best solution is chosen which has sufficient capacity and cost incurred to assign the task to that node is minimum. At last the pheromone on the path of ants that have explored that node will be updated.

$$\tau_{ij}^{new} = \rho \tau_{ij}^{old} + \Delta \tau_{ij}$$

where $\rho, 0 \le \rho < 1,$ is the persistence of the trail, i.e. $1-\rho$ represents evaporation.

Value of ρ is set to 0.75 ie. $\tau_{ij}^{old}(1-\rho)$ evaporates everytime.

$$\Delta\tau_{ij} = \begin{cases} \tau_{\max} * Q & \text{if task i is assigned to agent j in the solution[6]} \\ 0, & \text{otherwise} \end{cases}$$

where Q is 0.05 if the solution is feasible and 0.01 if solution is not feasible.

4. CONCLUSIONS AND FUTURE WORK

In this paper we designed an algorithm to solve the load balancing problem in a structured peer to peer system. The main contribution is an efficient algorithm that provides a number of feasible solutions. We plan to investigate following things in future: we tend to explore a method where we can adjust two or more tasks on a single trip of ants. We also plan to investigate algorithm performance in dynamic environment.

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