

A Survey of the Quadratic Assignment Problem

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ABSTRACT

The quadratic assignment problem (QAP) is very challenging and interesting problem that can model many real-life problems. In this paper, we will simply discuss the meaning of quadratic assignment problem, solving techniques and we will give a survey of some developments and researches.

Keywords: Quadratic Assignment Problem, formulation, Exact Algorithm, NP-complete, Bound, Heuristic.

1. INTRODUCTION

Quadratic assignment problem (QAP) was firstly introduced in 1957 by Koopmans and Beckmanns [26] as a mathematical model related to economic activities. Then QAP was used to model many applications in different areas such as operations research, parallel and distributed computing, and combinatorial data analysis, for example: locating machines, departments or offices within a plant, arranging indicators and controls in a control room to minimize eye fatigue, locating hospital departments, forest management, assignment of runners in a relay team etc.

2. DESCRIPTION OF THE PROBLEM

We will discuss generally a common problem, the linear assignment problem (LAP), then, we will define the quadratic assignment problem (QAP)

2.1 The Linear Assignment Problem (LAP)

The linear assignment problem (LAP) as used by Hanan and Kurtzberg [27], involves the assignment of n agents to n tasks. For each task assignment, there is a related cost c_{ij} of assigning agent i to task j . The assignment of each agent to one and only one task in a manner that minimizes the total cost is the objective. Mathematically, the formulation of this problem as follows:

$$\min \sum_{i=1}^n C_{i,j(i)} \quad \text{over all permutations } \pi \in S_n$$

where S_n is the set of permutations of $\{1, 2, \dots, n\}$, and $j = \pi(i)$ is the task assignment of agent i . Notice that there are $n!$ permutations from which to choose the optimal assignment, i.e., there are $n!$ distinct ways in which n tasks can be assigned to n agents. Also notice that for large values of n , examination of all possible permutations is infeasible. For example, assigning $n=10$ agents to 10 tasks as above, then there are $10!$ to be examined, or approximately 3.63 million different permutations. Obviously, we need more efficient algorithms for solving non-trivial forms of the LAP.

2.2 The Quadratic Assignment Problem

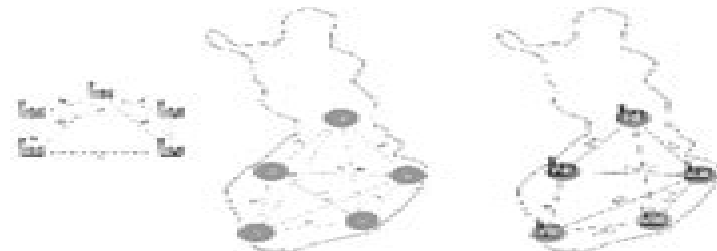
Simply, QAP can be illustrated as: n facilities have to be assigned to n different locations, assuming that a flow of value f_{ik} has to go from facility i

to facility j and that the distance between the locations k and l is $D_{kl} = [d_{kl}]$, the objective is to assign the facilities to the locations that minimizes the total cost which is the sum of the products flow \times distance, example: let the matrices A and B have the distance and flow matrices of a facility location problem.

$$A = \begin{bmatrix} 0 & 3 & 6 & 4 & 2 \\ 3 & 0 & 2 & 3 & 3 \\ 6 & 2 & 0 & 3 & 4 \\ 4 & 3 & 3 & 0 & 1 \\ 2 & 3 & 4 & 1 & 0 \end{bmatrix} \quad B = \begin{bmatrix} 0 & 10 & 15 & 0 & 7 \\ 10 & 0 & 5 & 6 & 0 \\ 15 & 5 & 0 & 4 & 2 \\ 0 & 6 & 4 & 0 & 5 \\ 7 & 0 & 2 & 5 & 0 \end{bmatrix}$$

As illustrated in Fig.1, optimal solution $p=[2,4,5,3,1]$. The factories to be allocated to specific locations are shown to the left. The picture to the right shows the optimal allocation of the factories.

Fig.1. A facility location problem



As with the LAP, there are $n!$ permutations from which to choose the optimal assignment. However, there is a difference between two problems that makes QAP considered more difficult.

The difference between LAP & QAP is that the LAP assignment of task j to agent i was made independently of the assignments of the other agents. With QAP the assignments are not independent, so when assign agent i to task j we must consider the assignments of all other agents who have nonzero affinity for agent i which represents the amount of face-to-face communication between agents.

3. PROBLEM FORMULATIONS

3.1 Koopmans-Beckman QAP

As we discussed above let $F = [f_{ij}]$ is a matrix of flows, $D = [d_{kl}]$ is a matrix of distances and consider n is the set of positive integers $\{1, 2, \dots, n\}$, and S_n be the set of permutations of $\{1, 2, \dots, n\}$. Then the Quadratic Assignment

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