Applying Bio-inspired Techniques to the p-Median Problem

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Abstract. Neural networks (NNs) and genetic algorithms (GAs) are the two most popular bio-inspired techniques. Criticism of these approaches includes the tendency of recurrent neural networks to produce infeasible solutions, the lack of generalize of the self-organizing approaches, and the requirement of tuning many internal parameters and operators of genetic algorithms. This paper proposes a new technique which enables feasible solutions, removes the tuning phase, and improves solutions quality of typical combinatorial optimization problems as the p-median problem. Moreover, several biology inspired approaches are analyzed for solving traditional benchmarks.

1 Introduction

Solving NP-hard combinatorial optimization problems has been a core area in research for many communities in engineering, operations research and computer science. The interdisciplinary features of most NP-hard optimization problems have caused a large amount of papers from many researches that have proposed numerous and different algorithms to overcome the many difficulties of such problems. Several researches used algorithms based on the model of organic evolution as an attempt to solve hard optimization problems [1]. Due to their representation scheme for search points, genetic algorithms [2] are one of the most easily applicable representatives of evolutionary algorithms.

The idea of using neural networks to provide solutions to NP-hard optimization problems have been pursued for over decades. Hopfield and Tank [3] showed that the travelling salesman problem (TSP) could be solved using a Hopfield neural network. This technique requires minimization of an energy function containing several terms and parameters. Due to this technique was shown to often yield infeasible solutions, researchers tried to either modify the energy function or optimally tune the numerous parameters involved so that the neural network would converge to a feasible solution.

Both GAs and NNs are addressed in this work as competed paradigm for solving combinatorial optimization problems. There exist many NP-hard combinatorial optimization problems, although in this paper we selected the well-known

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p-median problem as a preliminary study of the two bio-inspired techniques for solving NP-hard combinatorial optimization problems.

The outline of the paper is organized as follows: Section 2 presents the problem and a primarily integer programming formulation. In section 3 the analyzed bio-inspired techniques are described. The experimental results are showed in section 4, and the paper concludes summarizing our findings in section 5.

2 Problem Formulation

The p-median problem has been studied during decades and it is one of the most popular and well-known facility location problems. The first reference to this problem is found in the work of Hakimi (1964) [4] who proposed such optimization problem. The p-median problem concerns the location of p facilities (medians) in order to minimize the total weighted distances from each point (population center or customer) to its nearest facility. Kariv and Hakimi (1979) [5] showed that the p-median problem on a general network is NP-hard. Revelle and Swain [6] provided an integer programming formulation for the discrete p-median problem, which is given below

Minimize

$$\sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij}x_{ij} \tag{1}$$

Subject to :

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

$$\sum_{j=1}^{n} x_{jj} = p \tag{3}$$

$$x_{ij} \leq x_{jj} \quad i = 1, ..n; j = 1, ..n \tag{4}$$

where

n is the number of demand points

p is the number of facilities or medians

d_{ij} is the distance (cost) between the point i and the facility j

$x_{ij} = \begin{cases} 1 & \text{if the point } i \text{ is assigned to the facility } j \\ 0 & \text{otherwise} \end{cases}$

$x_{jj} = \begin{cases} 1 & \text{if the point } j \text{ is a facility} \\ 0 & \text{otherwise} \end{cases}$

The restrictions (2) prevent that all demand points are assigned to a facility. The constraints (3) establish the number of facilities (medians) to locate, and the last conditions (4) assure that a demand point is assigned to an opened facility.

A number of heuristic solution techniques have been developed in an effort to solve large-scale instances to near-optimality with a reasonable computational