The Close Enough Traveling Salesman Problem: A Discussion of Several Heuristics

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Summary. The use of radio frequency identification (RFID) allows utility companies to read meters from a distance. Thus a meter reader need not visit every customer on his route, but only get within a certain radius of each customer. In finding an optimal route – one that minimizes the distance the meter reader travels while servicing each customer on his route – this notion of only needing to be close enough changes the meter reading problem from a standard Traveling Salesperson Problem (TSP) into a variant problem: Close Enough TSP (CETSP). As a project for a graduate course in network optimization various heuristics for finding near optimal CETSP solutions were developed by six groups of students. In this paper we survey the heuristics and provide results for a diverse set of sample cases.

Key words: Traveling salesman problem; radio frequency identification; electronic meter reading.

1 Introduction

Historically when a utility company measures the monthly usage of a customer, a meter reader visits each customer and physically reads the usage value at each site. Radio frequency identification (RFID) tags at customer locations can remotely provide data if the tag reader is within a certain radius of the tag. This changes the routing problem from one of a standard traveling salesman problem (TSP) to what we call a "Close Enough" TSP (CETSP). Thus the route lengths of the meter readers can be drastically reduced by developing heuristics that exploit this "close enough" feature.

We consider such a meter reading routing problem where each customer is modeled as a point in the plane. Additionally there is a point that represents the depot for the meter reader. A CETSP tour must begin and end at the depot and travel within the required radius, r, of each customer. For simplicity in the cases tested here the meter reader was not restricted to a road network.

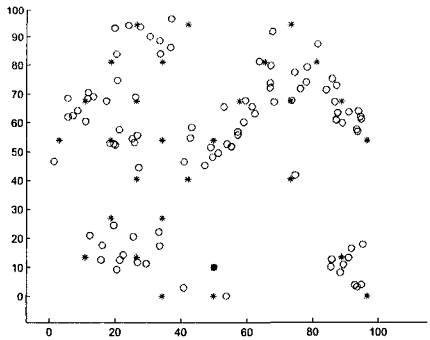

Fig. 1. An example of a supernode set on 100 nodes, with radius 9, and the depot located at (50,10). The circles represent the customer nodes, and the asterisks are the supernodes.

All distances are Euclidean and the objective is to minimize the total distance traveled. The solution to a standard TSP on the customer nodes obviously provides an upper bound for the CETSP.

Essentially the CETSP is a TSP with a spatial window. Thus it is conceptually similar to the TSP with a time window. Several heuristics are discussed in the work of Solomon [9]. In spite of the similarities the heuristics for the TSP problem with a time window do not directly apply to the CETSP. This is because we do not simply change the order of the points visited, we actually change the location of the points themselves. So the CETSP has an uncountable solution space.

As a class project six teams developed heuristics to produce solutions to this problem. This paper highlights the innovative developments from these projects. In Section two we discuss the proposed heuristics. In the third Section we present the numerical results across a test bed of cases. We conclude with some suggestions for further work in Section four. Psuedo code for some of the heuristics is provided in the appendix.

2 Heuristics

All of the heuristics developed have three distinct steps. Given an initial set C of customer nodes (c-nodes), the first step is to produce a *feasible supernode* set, S. A feasible supernode set is a set of points (containing the depot node) with the property that each customer node is within r units of at least one point in the set. In Figure 1 the set of asterisks $(*)$ represents a feasible supernode set since each customer (circle) is within r units $(r = 9)$ of at least one asterisk. After producing S the second step is to find a near optimal TSP