Effectiveness of Computer Algorithms for Traveling Salesman Problem

Erik Chen. ec.erikchen@gmail.com
Arnold O. Beckman High School, Class of 2018
USC Viterbi Department of Industrial and Systems Engineering, SHINE 2017

Introduction

- Professor John Carlsson is researching ways to optimize delivery systems
- Expansion of ecommerce growth need for package delivery optimization
- Traveling salesman problem – finding the shortest path throughout multiple points
- Many algorithms and heuristics used to simplify TSP (traveling salesman problem) since TSP is NP-hard
- Horsefly problem (using drones as a means for delivery services) – an application of TSP in real world
- Experiment with the different algorithms developed from MATLAB and methods used to solve these problems

Objective & Impact of Professor's Research

Below are two articles published by Professor Carlsson:

Coordinated Logistics with a truck and a drone

- Horsefly problem in real life
- Use drones to deliver packages which makes routing for trucks smaller
- Popular new innovation – Amazon Prime Air

Household-Level Economics of Scale in Transportation (2015)

- Study of the effectiveness of delivery systems over running errands
- Focus on CO2 emissions with either errands or delivery
- Results show that significant amount of delivery systems needed before it becomes more effective

Skills Learned

MATLAB (coding language based on matrices)

- coding multiple representations of different algorithms/heuristics to see the different results
- Developing proprietary programs to recreate the different algorithms (nearest neighbor, random insertion, cheapest insertion)
- Bearwood-Halton-Hammersley Theorem (proportionality to √n)

Experiment9.m | Experiment8.m | Experiment10.m | cheapestInsertion.m

```
function [dist,order]=cheapestInsertion(x,y)
n=length(x);
k=6;
Rnd_perm=randperm(n);
order=1:n;
x=x(Rnd_perm);
y=y(Rnd_perm);
order=order(Rnd_perm);
if n<k
    dist=bruteForceDistance(x,y);
    order=bruteForceOrder(x,y);
    %drawalot(x,y,order);
else
    base_x=zeros(1,n);base_y=zeros(1,n);base_order=zeros(1,n);
    base_x(1,1:k)=x(1,1:k);
    base_y(1,1:k)=y(1,1:k);
    base_order(1,1:k)=order(1,1:k);
    optOrder=bruteForceOrder(x(1:k),y(1:k));
    base_x=[base_x(optOrder),zeros(1,n-k)];
```

Figure 1: Example of code of one of many algorithms used

Basic Graph Theory

- Trees – Connected set of points with no loop
- Minimum Spanning Tree – smallest cost for connecting all points
- Eulerian Tour – go through all points twice

Transformations into Metric TSP Problems

- Many computer algorithms and programs to solve metric TSP problems (finding the shortest path)
- Not all problems are set up in metric TSP form
- Use transformations to change to metric TSP

Projects and Experiments

- During experiments, we tested the effectiveness of the algorithms versus human intuition
- Beta of human intuition better than any heuristics in small scale

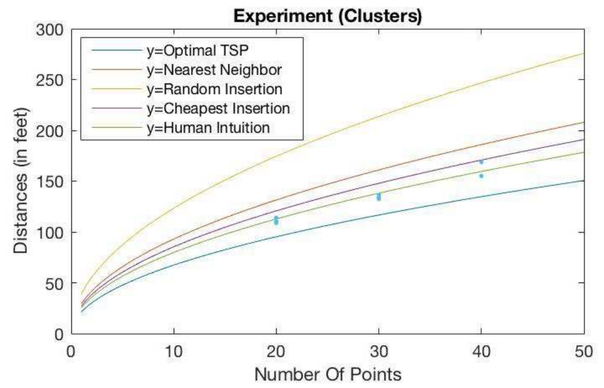

Figure 2: Graph of how human intuition performs vs different algorithms

- Used Cheapest Insertion algorithm to chart possible paths to resupply Albertsons stores

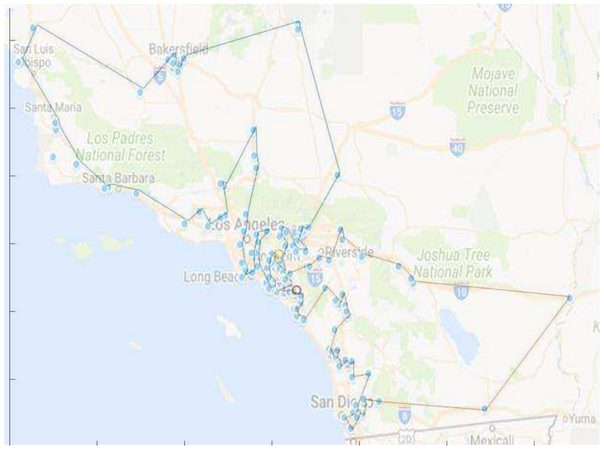

Figure 3: Map of all Albertsons locations in southern California and a path to effectively restock them

Future Research

Next Steps: use drones to study the horsefly problem

- Drones mounted on trucks lessen the time needed to deliver packages

How This Relates to Your STEM Coursework

Through this research experience, I found similarities to my STEM coursework are logic and problem solving skills. Differences are research is based on a very specific topic while schoolwork covers multiple areas of a general topic. Also, teachers structure their lectures and labs with known results while research leads to unknown territory.

Next Steps

While we completed many experiments and gathered significant data during SHINE, I want to have the opportunity to continue the data collection based on the horsefly problem.

Acknowledgements

Thank you Professor Carlsson, PhD mentors Yang Cao and Shichun Hu, SURE mentor Ramy Elbakari, lab partner Miléna DeGuere, SHINE director Dr. Katie Mills and her staff.