Solving the Open Vehicle Routing Problem: New Heuristic and Test Problems

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Introduction

- Open Vehicle Routing Problem (OVRP)

  A vehicle does not return to the depot after servicing the last customer on a route

  Each route in the OVRP is a Hamiltonian path

- Two objectives

  Minimize the total number of vehicles

  Minimize the total distance traveled

  We believe the cost of an extra vehicle far exceeds the reduction in distance that can be achieved by an additional route

Introduction

- Real-world applications of the OVRP

  FedEx generates incomplete delivery routes for airplanes (Bodin et al. 1983)

  FedEx Home Delivery service to residential-only customers (Levy 2005)

  Newspaper home delivery problem (Levy 2005)

  If a company contracts drivers with vehicles and drivers are not required or paid to return to the depot, then the application fits the OVRP framework

Literature Review

- Algorithms for the OVRP

  Since 2000, seven algorithms have been developed to solve OVRP

  - Two use threshold accepting
  - Three use tabu search
  - One uses large neighborhood search
  - One uses the minimum spanning tree

Literature Review

- Seven algorithms for the OVRP

Sariklis and Powell (2000)

Cluster First, Route Second (CFRS)

Brandao (2004)

Tabu Search Algorithm (TSA)

Tarantilis, Diakoulaki, and Kiranoudis (2004)

Adaptive Memory-based Tabu Search BoneRoute (BR)

Tarantilis, Ioannou, Kiranoudis, and Prastacos (2004)

Backtracking Adaptive Threshold Accepting (BATA)

Literature Review

- Seven algorithms for the OVRP

Tarantilis, Ioannou, Kiranoudis, and Prastacos (2005)

List-Based Threshold Accepting (LBTA)

Fu, Eglese, and Li (2005)

Tabu Search Heuristic (TS)

Pisinger and Ropke (2005)

Adaptive Large Neighborhood Search (ALNS)

Record-to-Record Travel

- A deterministic variant of simulated annealing developed by Dueck (1993)

- Framework of RTR (for a minimization problem)

  Record (R) : Best solution found so far

  Deviation (D) : Amount of uphill move allowed
  ($D = k\% \times R$)

  Rule : If Obj (S′) < R + D, then
  solution S is replaced by S′

Solving the OVRP with RTR Travel

- Adapted from RTR for solving large-scale VRPs (Li, Golden, and Wasil 2005) to solve the open vehicle routing problem (ORTR)

- Features of ORTR

  Fixed-length neighbor list with 20 customers (tradeoff between running time and solution quality)

  Sweep algorithm to generate an initial solution with a minimum number of vehicles

  Combine two routes (if possible) to reduce the total number of vehicles even if the total distance increases

Computational Results

- Benchmark data sets
  - 16 test problems
    - C1 to C14 from Christofides et al. (1979)
    - F11, F12 from Fisher (1994)
  - 50 to 199 customers
  - 7 problems have a route-length restriction

- ORTR coded in Java
  - Athlon 1 GHz, 256 MB RAM, Linux

Computational Results

- Illustrative results

Problem	*Kmin*	Minimize Vehicles with Least Distance
C1	5	408.5 TSF
C2	10	567.14 ALNS 25K, ALNS 50K, ORTR
C6	5	400.6 TSF (6 vehicles)
C14	10	591.87 ALNS 25K, ALNS 50K, ORTR (11 vehicles)
F12	7	769.66 ORTR

Problem	*Kmin*	Minimize Vehicles with Least Number of Vehicles
C1	5	408.5 TSF
C2	10	564.06 BR, BATA, LBTA (11 vehicles)
C6	5	400.6 TSF (6 vehicles)
C14	10	469.3 TSR (11 vehicles)
F12	7	769.66 ORTR

Computational Results

- Aggregate results for top four procedures

	TSR	ALNS 25K	ALNS 50K	ORTR
Total Number of Vehicles (sum of *Kmin* = 147)	162	156	156	159
Total Distance	10,123	10,199	10,194	10,191
Time (s)	6,347	13,350	22,200	1,756

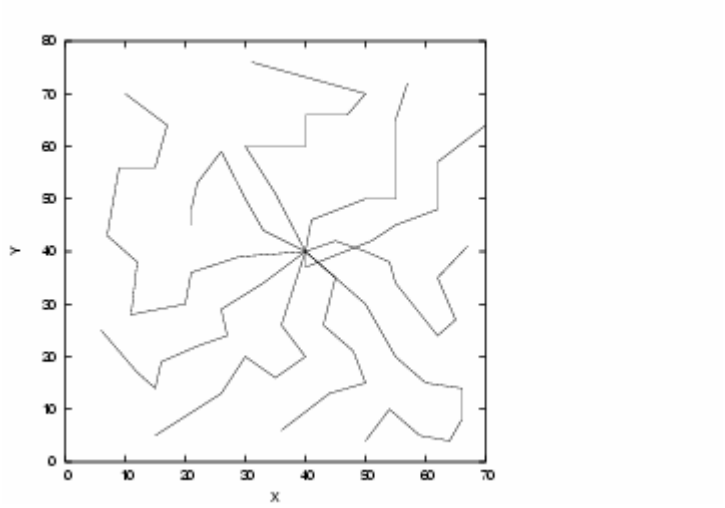
Computational Results

- When the number of vehicles is minimized
  - ALNS 50K generated best solution to 9 problems (56%)
  - ALNS 25K 7 problems (44%)
  - ORTR 5 problems (31%)
- When the total distance traveled is minimized
  - TSR generated best solution to 5 problems (31%)
  - ORTR 4 problems (25%)

Computational Results

- ORTR solutions

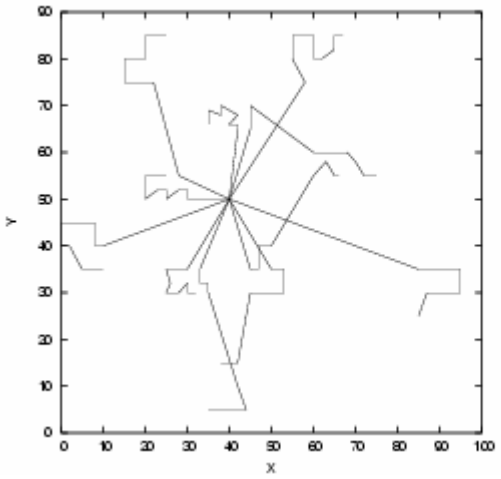
  Problem C2, n = 75, solution value = 567.14



Computational Results

- ORTR solutions

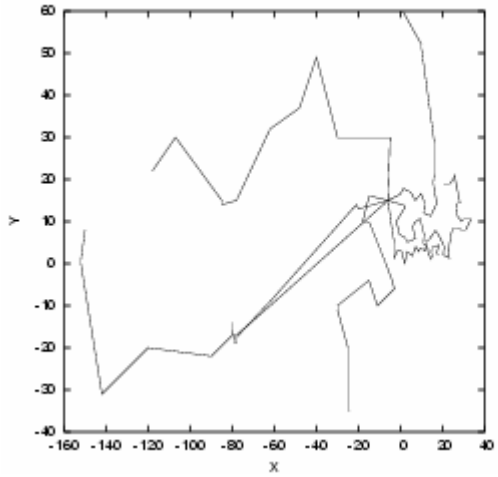
  Problem C14, n = 100, solution value = 591.87



Computational Results

- ORTR solutions

  Problem F12, n = 134, solution value = 769.66



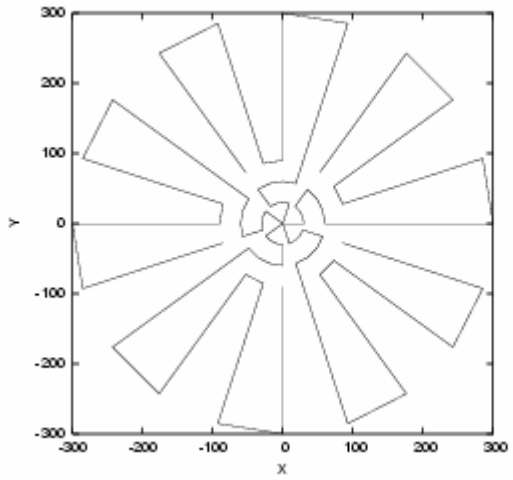
Large-Scale Test Problems

- New test problems
  - 8 problems
    - LSVRPs from Golden et al. (1998)
  - 200 to 480 customers
  - No route-length restriction
  - Geometric symmetry
    - Customers in concentric circles around the depot
  - Visually estimate solutions

Large-Scale Test Problems

- Visually estimated solutions

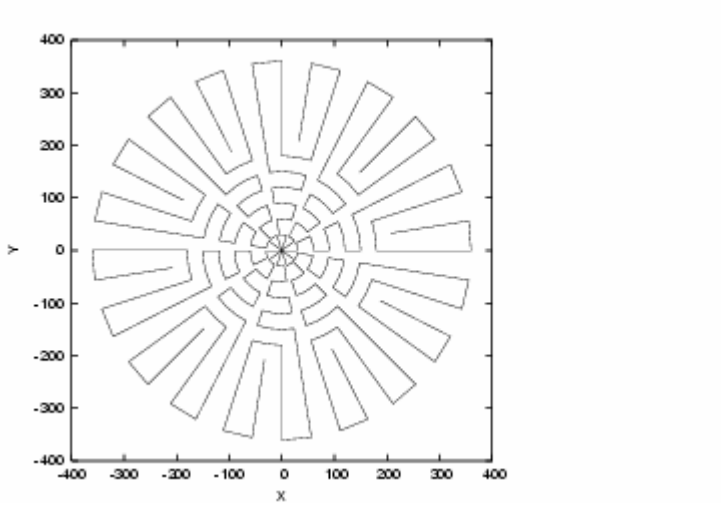
  Problem O1, n = 200, estimated solution value = 6151.77



Large-Scale Test Problems

- Visually estimated solutions

  Problem O8, n = 480, estimated solution value = 12513.11



Computational Results

- Results for ORTR on new test problems

Problem	*n*	*C*	*Kmin*	ORTR	Time(s)	% Improvement over Estimated Solution
O1	200	900	5	6018.52	365.3	2.17
O2	240	550	9	4584.55	439.6	4.20
O3	280	900	7	7732.85	492.8	1.28
O4	320	700	10	7291.89	573.6	0.64
O5	360	900	8	9197.61	766.5	1.14
O6	400	900	9	9803.80	977.2	1.22
O7	440	900	10	10374.97	935.4	1.26
O8	480	1000	10	12429.56	1126.8	0.67
Total Vehicles			68	68		
Average						1.57

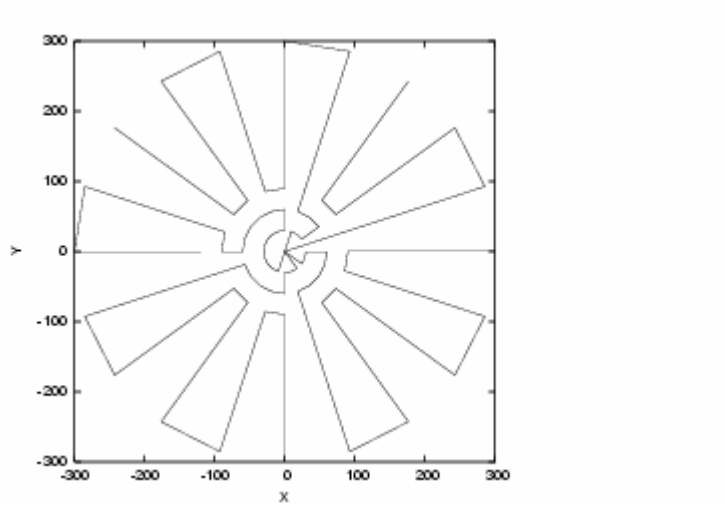
C is vehicle capacity

Estimated solutions used 72

Large-Scale Test Problems

- ORTR solutions

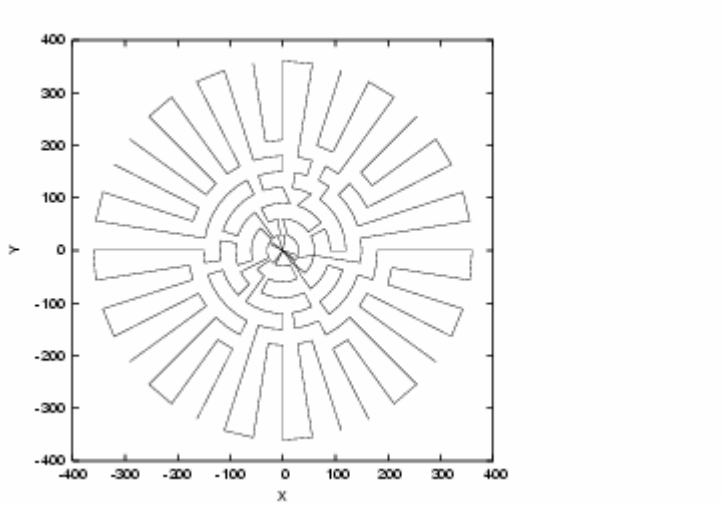
  Problem O1, n = 200, estimated solution value = 6018.52



Large-Scale Test Problems

- ORTR solutions

  Problem O1, n = 480, estimated solution value = 12429.56



Conclusions

- Increased interest in the OVRP in last five years
  - Contractors used to deliver packages and newspapers
  - Wide variety of new algorithms to solve problems
- Three algorithms were accurate
  - Adaptive large neighborhood search (ALNS 25K, ALNS 50K)
  - Tabu search (TSR)
  - Record-to-record travel (ORTR)
- Generated eight large-scale test problems
  - ORTR found good solutions in a few minutes