Generating and Solving Very Large-Scale Vehicle Routing Problems

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Introduction

- Capacitated Vehicle Routing Problem (VRP)

  Generate a sequence of deliveries for each vehicle in a homogeneous fleet based at a single depot so that all customers are serviced and the total distance traveled is minimized

  Vehicle constraints
    - Fixed capacity
    - Leave and return to depot
    - Route-length restriction

  Customer constraints
    - Known demand
    - Serviced in one visit

Introduction

▶ Recent Computational Efforts

- Large-scale vehicle routing problems (LSVRP)
  - Developed by Golden et al. in 1998
  - 20 problems
  - 200 to 483 customers
  - 8 problems with route-length restrictions
  - 3 geometric patterns (circle, square, star)
    - Visually estimate solutions

- General-purpose metaheuristics have produced high-quality solutions

Deterministic annealing
Tabu search

Introduction

- Outline of Presentation

  - Review recent solution procedures
    - Six algorithms
    - Improved version of record-to-record travel
    - Computational results on 20 LSVRPs

  - Develop new very large-scale VRPs
    - 12 VLSVRPs with geometric symmetry
    - 560 to 1200 customers
    - Route-length restrictions

  - Computational results with improved RTR travel

Solution Procedures

- Six Algorithms (1998 to 2003)

Deterministic annealing

Record-to-record travel RTR	Golden et al. (1998)
Backtracking adaptive threshold accepting BATA	Tarantilis (2003)
List-based threshold accepting LBTA	Tarantilis (2003)

Tabu search

Network flow-based tabu search	Golden et al. (1998)
Adaptive memory-based tabu search BoneRoute	Tarantilis and Kiranoudis (2002)
Granular tabu search GTS	Toth and Vigo (2003)

Solution Procedures

- Improved RTR Travel (VRTR)
  - Accurate, fast, simple, and flexible
  - Implement variable-length neighbor list
    - Start with fixed-length list of $k = 40$
    - For node i, remove all edges with length greater than $\alpha \times L$, where L is the maximum length among edges in i's neighbor list
    - As α decreases, so does running time and accuracy suffers

Motivated by work of Cordeau et al. (2002)

Like granular neighborhood of Toth and Vigo

Solution Procedures

▶ VRTR Travel Algorithm

λ = 0.6, 1.4, 1.6

Step 1. Generate an initial feasible solution using the modified Clarke and Wright algorithm.

Set Record = objective function value of current solution.

Set Deviation = 0.01 × Record.

Step 2. Improve the current solution.

One-point moves with RTR travel, two-point moves with RTR travel between routes, and two-opt move with RTR travel.

Maintain feasibility.

Update Record and Deviation.

Solution Procedures

- VRTR Travel Algorithm

Step 3. For the current solution, apply one-point move (within and between routes), two-point move (between routes), two-opt move (between routes), and two-opt move (within and between routes). Only downhill moves are allowed.

Update Record and Deviation.

Step 4. Repeat until no further improvement for $K = 5$ consecutive iterations.

Step 5. Perturb the solution.

Step 6. Keep the best solution generated so far.

Return to Step 1 and select a new value for λ.

Computational Experiments

- ▶ Computational Results
  - 20 LSVRPs
    - Best-known solution to each problem
      - 7 visually estimated
      - 3 by VRTR ← Different parameter values
      - 10 by ORTR ← Other experiments with RTR
  - Five procedures that solve all problems
    - RTR GTS BATA LBTA VRTR

Single set of parameter values

Computational Experiments

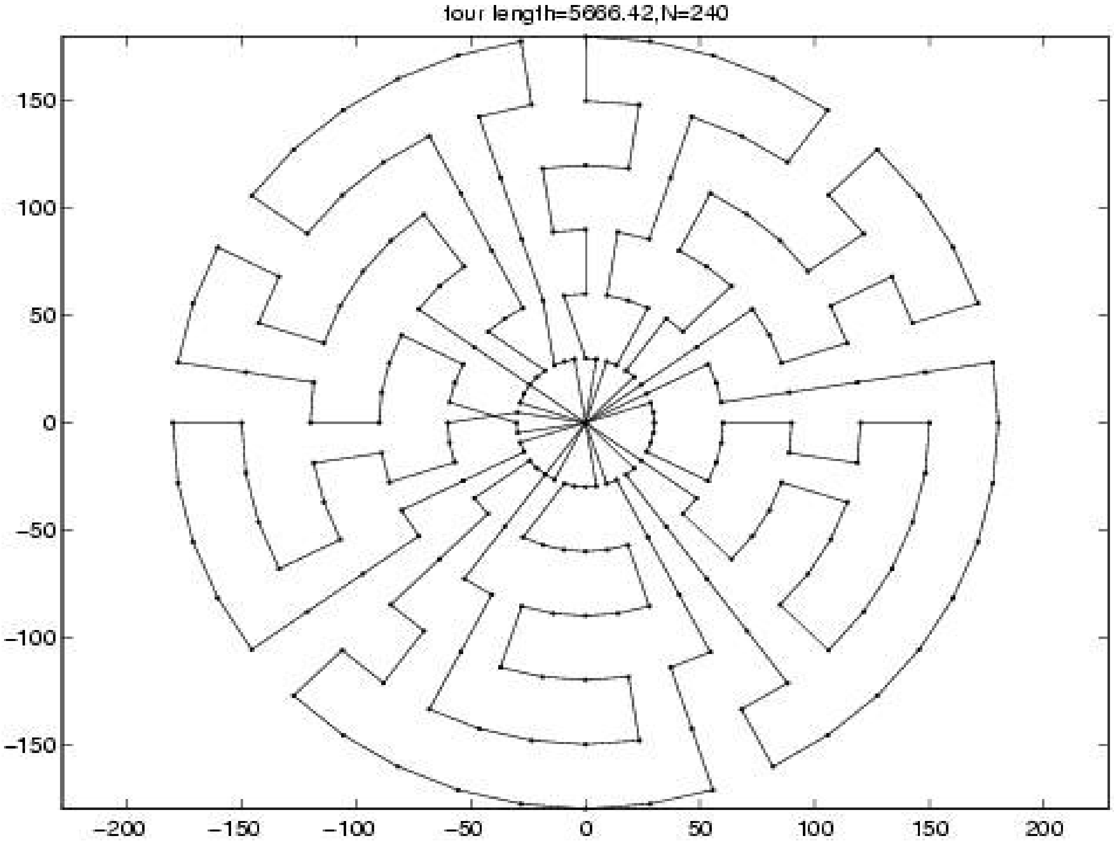
Computational Results

Algorithm	Average % Above Best-known Solution	Average Computing Time (min)	CPU
RTR	3.56	37.15	P 100 MHz
GTS	2.52	17.55	P 200 MHz
BATA	1.62	18.41	P 233 MHz
LBTA	1.59	17.81	P 233 MHz
VRTR			A 1 GHz
$\alpha = 1$	0.70	1.13	
$\alpha = 0.4$	0.77	0.68	

Use 50% to 60% of the edges

Computational Experiments

- VRTR Solution ($\alpha = 1$) for LSVRP with 240 Customers



Computational Experiments

- Three Comments

  1. Adaptive memory-based tabu search

     BoneRoute algorithm of Tarantilis and Kiranoudis

     Applied to only eight problems with route-length restrictions

Algorithm	Average % Above Best-known Solution	Average Computing Time (min)	CPU
BR	0.68	42.05	P 400 MHz

Seven parameters with “standard settings”

Computational Experiments

- Three Comments

2. Head-to-head competition on 20 LSVRPs

RTR GTS BATA LBTA VRTR

First Place

VRTR generates nine best solutions

Second Place

GTS generates two best solutions

Honorable Mention

Visually estimated solutions (problems 2 to 8) from Tarantilis and Kiranoudis are very good

No algorithm produced better solutions!

Computational Experiments

- ▶ Three Comments

Christofides et al. (1979)

3. Results on seven benchmark VRPs

50 to 199 customers

No service times for customers

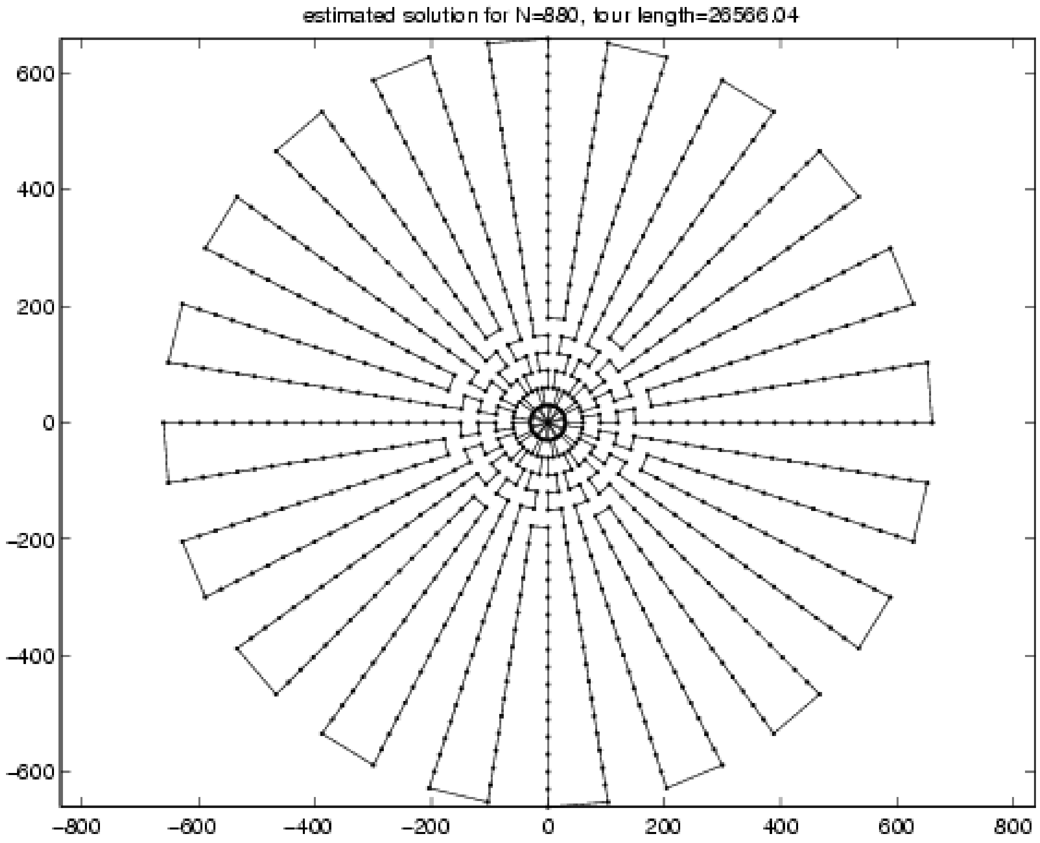
Algorithm	Average % Above Best-known Solution	Average Computing Time (min)	CPU
VRTR			A 1 GHz
$\alpha = 1$	0.62	0.41	
$\alpha = 0.6$	0.62	0.35	
$\alpha = 0.4$	0.41	0.32	
GTS	0.47	3.10	P 200 MHz

New Problems

- ▶ Very Large-Scale Vehicle Routing
  - Very large-scale vehicle routing problems (VLSVRP)
    - 12 problems
    - 560 to 1200 customers
    - All problems with route-length restrictions
    - Geometric pattern (circle)
      - Visually estimate solutions
    - Easy to construct
      - Problem generator

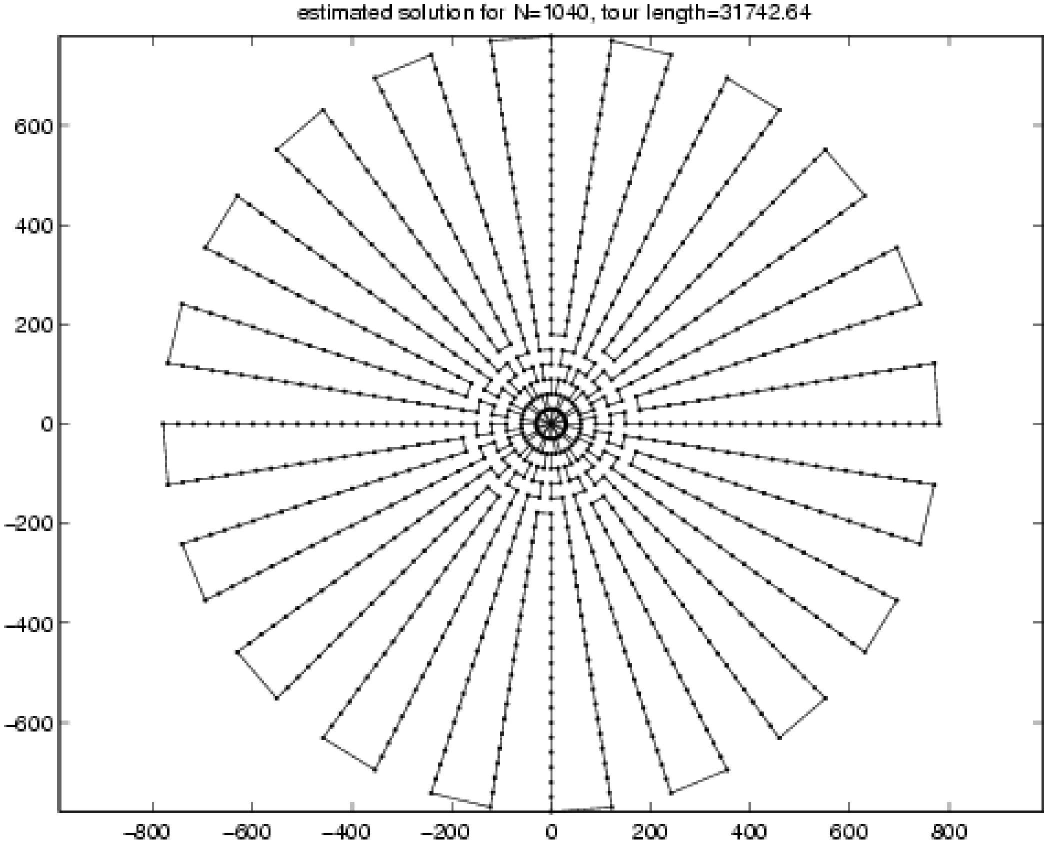
New Problems

- VLSVRP with 880 Customers



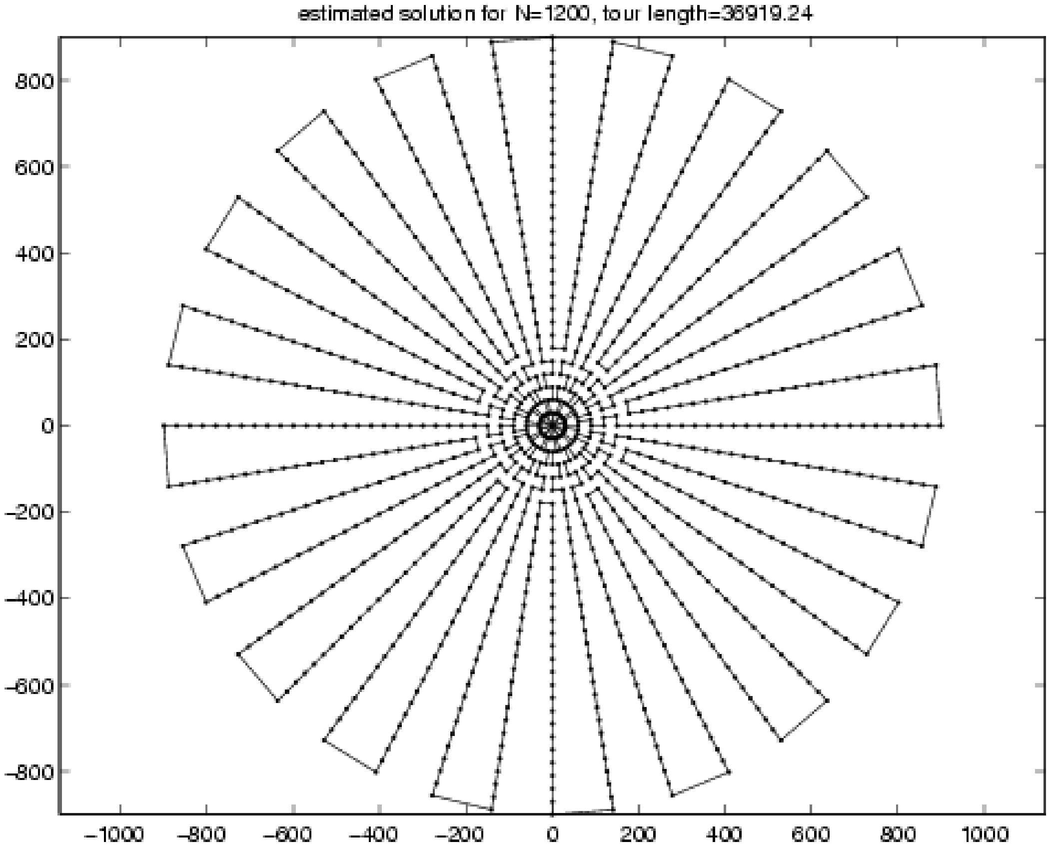
New Problems

- VLSVRP with 1040 Customers



New Problems

- VLSVRP with 1200 Customers



Computational Experiments

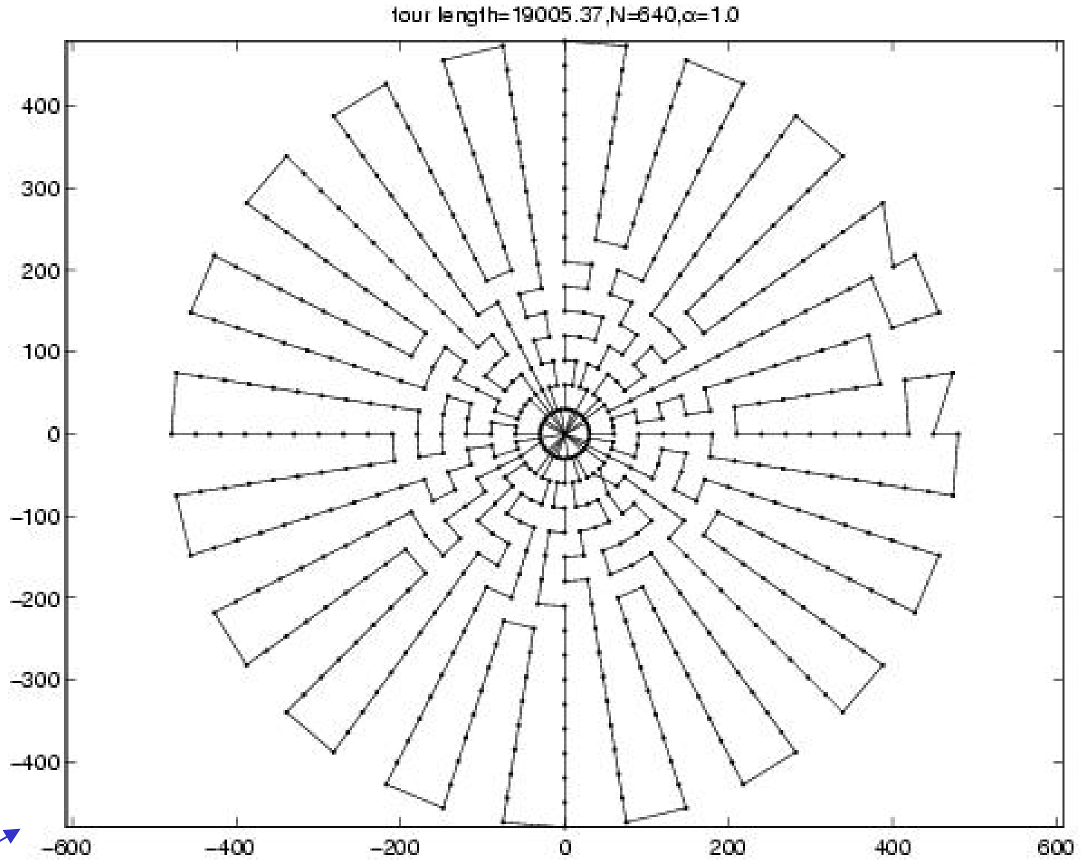
- VLSVRPs: Computational Results

Algorithm	Average % Above Best-known Solution	Average Computing Time (min)	CPU
VRTR			A 1 GHz
α = 1	1.10	3.16	
α = 0.6	1.20	2.94	
α = 0.4	2.28	2.08	

Visually estimated solution is best-known solution for 10 problems

Computational Results

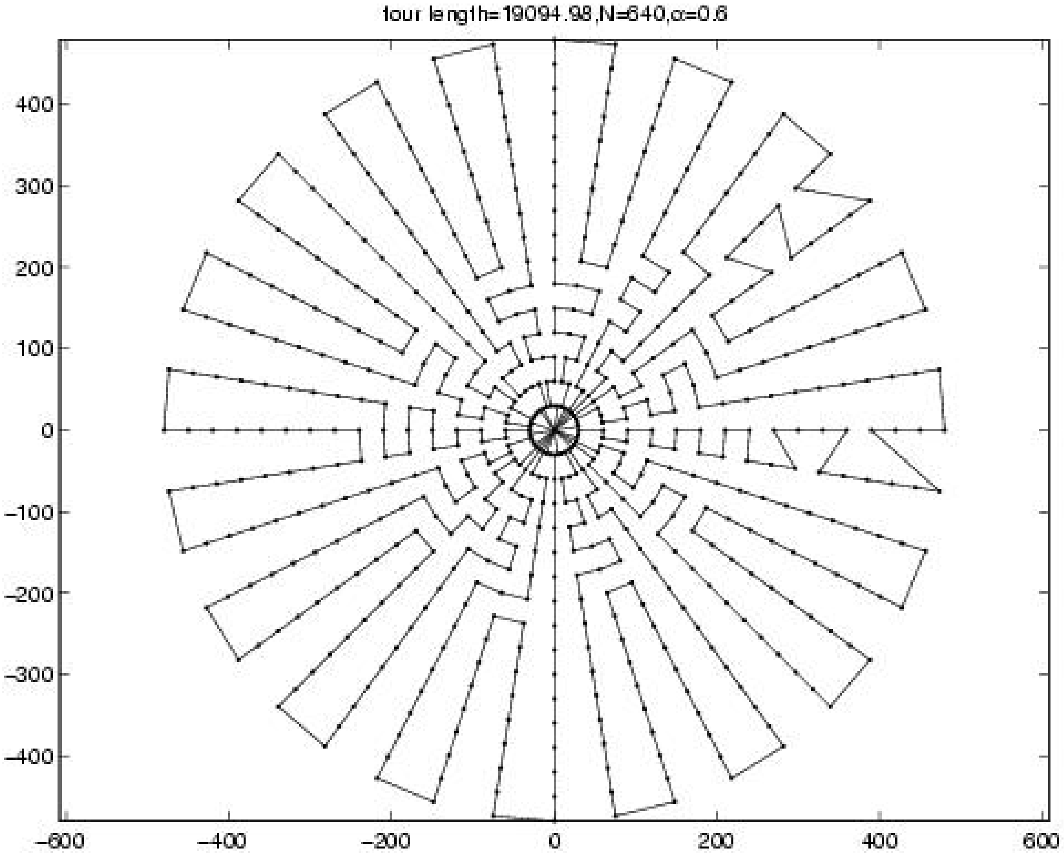
- VRTR Solution (α = 1) for VLSVRP with 640 Customers



Visually estimated solution = 18801.13

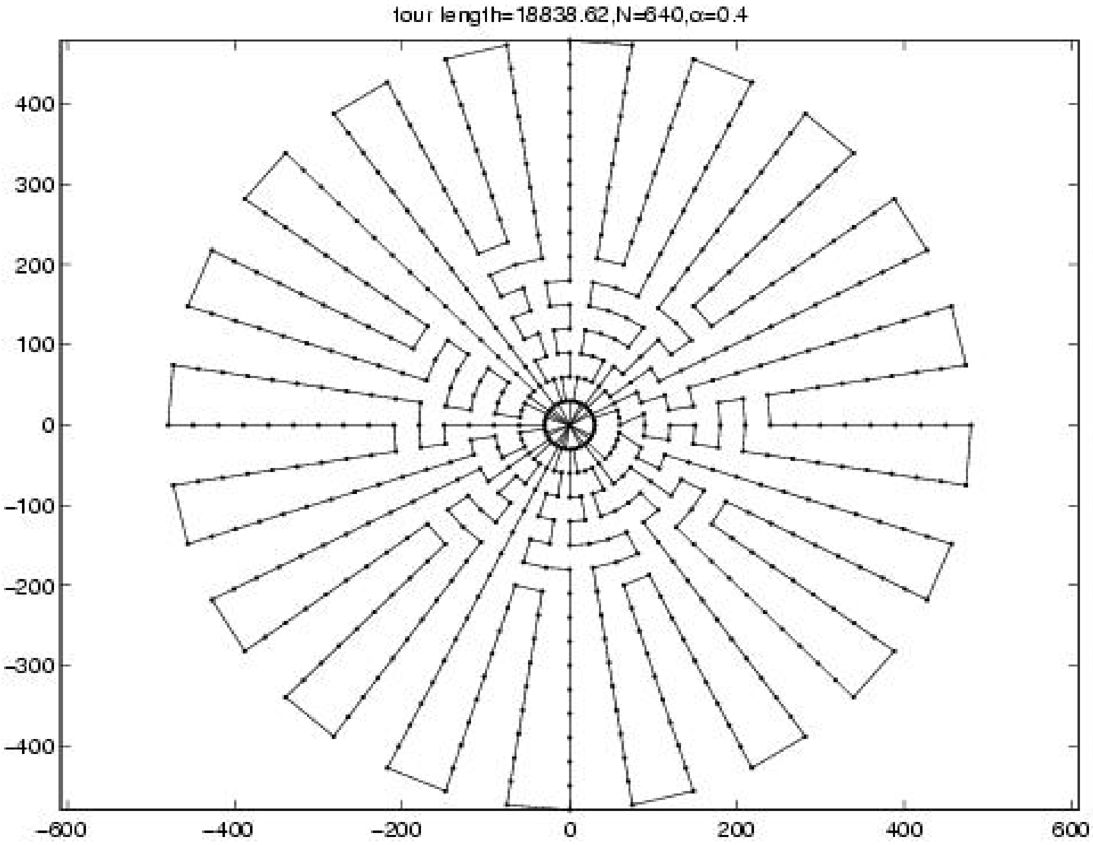
Computational Results

- VRTR Solution ($\alpha = 0.6$) for VLSVRP with 640 Customers



Computational Results

- ▶ VRTR Solution (α = 0.4) for VLSVRP with 640 Customers



Conclusions

- Summary

  Reviewed procedures for solving LSVRPs

  Generated a new set of 12 VLSVRPs with 560 to 1200 customers

  Developed improved version of RTR travel algorithm with a variable-length neighbor list

    VRTR is very fast and highly accurate in solving 20 LSVRPs and 12 VLSVRPs

  Paper forthcoming in *Computers & Operations Research* (available at www.sciencedirect.com)