Solving the Time Dependent Traveling Salesman Problem

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Introduction

- Time Dependent Traveling Salesman Problem (TDTSP)

  Some customers are located in the center of the city

  During morning rush hour traveling in the center of the city takes more time

  A good tour should avoid visiting customers in the center of the city when it is congested

Introduction

▶ Literature Review

Bentner et al. (2001) and J. Schneider (2002) used the Bier127 problem from TSPLIB to study the TDTSP

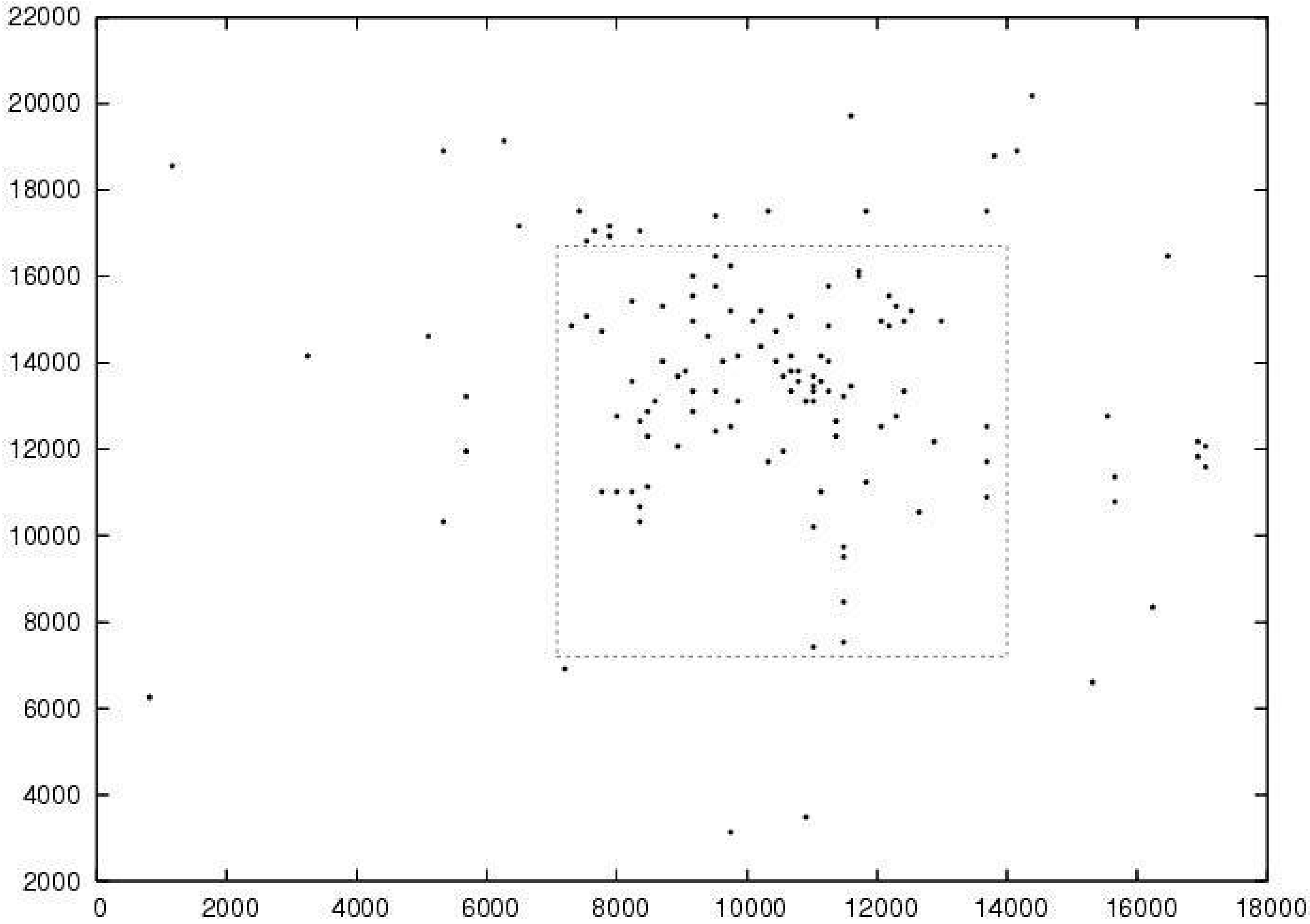
Traffic jam occurs inside a rectangular region in the afternoon from 12 pm to 3pm

Traveling inside the rectangular region during rush hour is penalized by a jam factor $f > 1$

Simulated annealing was used to generate a solution for each jam factor

Introduction

Bier127 Problem

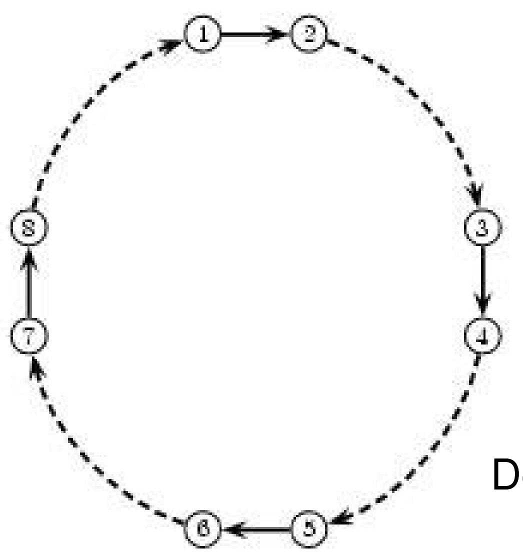


Algorithm: Record-to-record Travel (RTR)

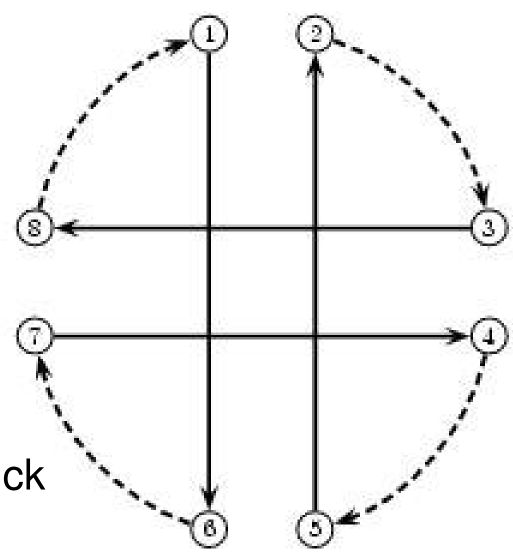
- Generate an initial solution by modified Clarke and Wright algorithm with parameter λ
- Apply two-opt moves and one-point moves and allow uphill moves
- Improve the current solution by allowing only downhill moves
- Continue until no improvement over five consecutive iterations
- Save the best solution among all values of λ

Algorithm: Chained Lin-Kernighan (CLK)

- Generate an initial solution by modified Clarke and Wright algorithm with parameter λ
- Apply variant of chained Lin-Kernighan algorithm
- Perturb the current solution and repeat chained Lin-Kernighan
- Save the best solution among all values of λ



Double-bridge kick



Old Assumption

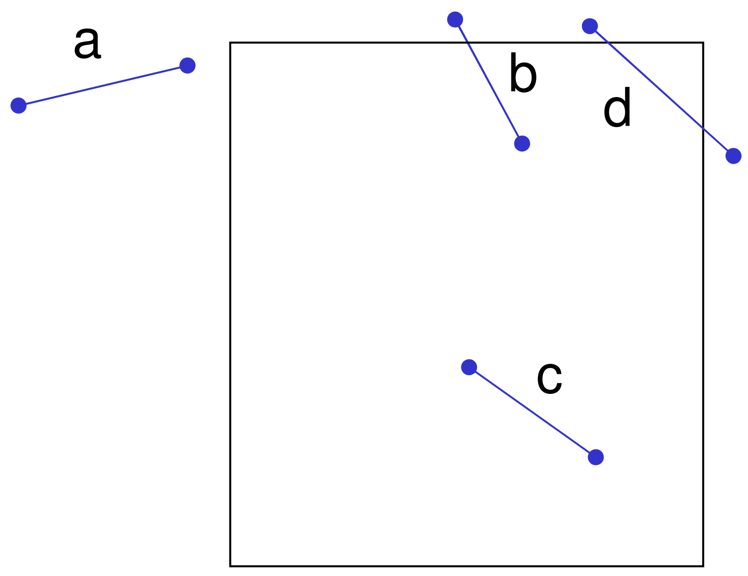
- Traffic jam occurs on all edges with both end points in the rectangular jam region between 12pm and 3pm

  a will not be penalized

  b will not be penalized

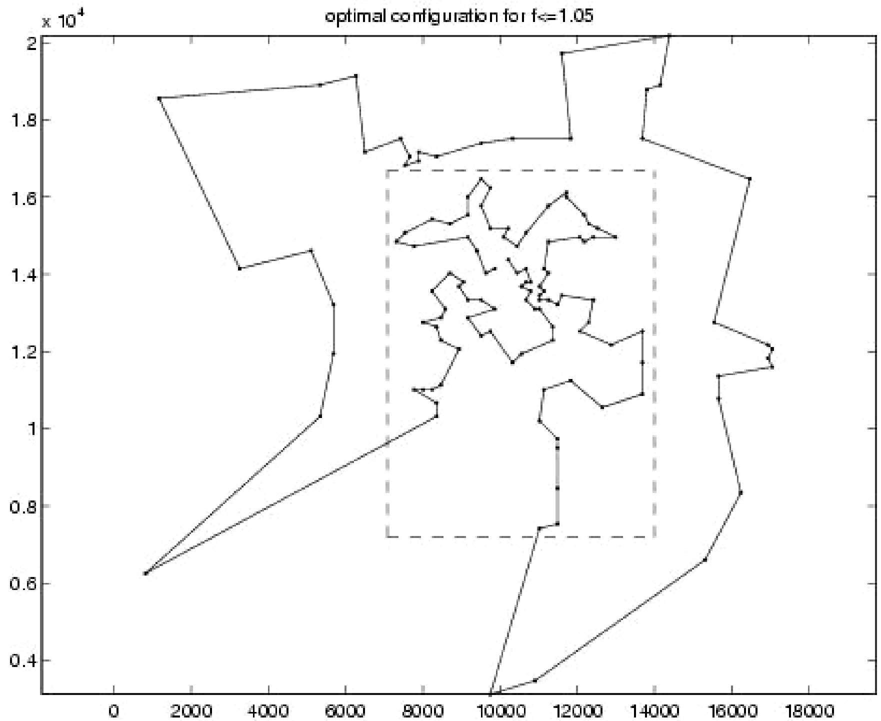
  c will be penalized

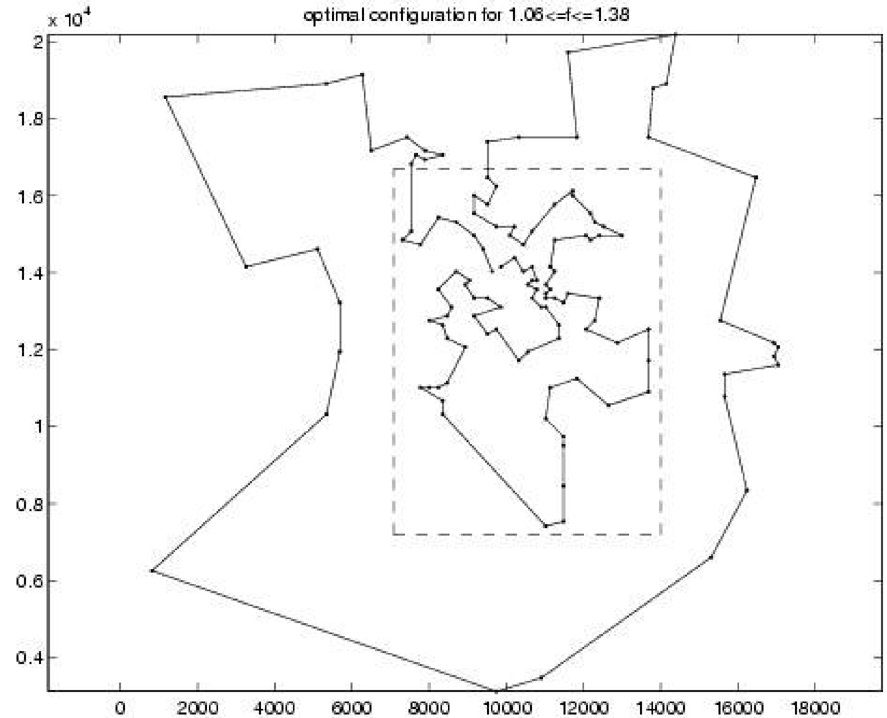
  d will not be penalized



Old Assumption

▶ Computational Results: RTR





Old Assumption

▶ Computational Results of RTR

Jam Factor	Time(min)	Tour Length	Percent Above Best Known	Best-known Solution
1.00	2.61	118293.524	0.00	118293.524
1.03	4.31	118796.154	0.04	118749.356
1.06	3.98	119857.323	0.60	119153.582
1.39	3.10	120453.554	0.00	120453.554
2.02	5.58	121298.538	0.14	121125.195
3.00	4.34	122222.204	0.91	121125.195
10.00	3.67	121167.051	0.03	121125.195
100.00	4.47	122280.886	0.95	121125.195

New Assumption

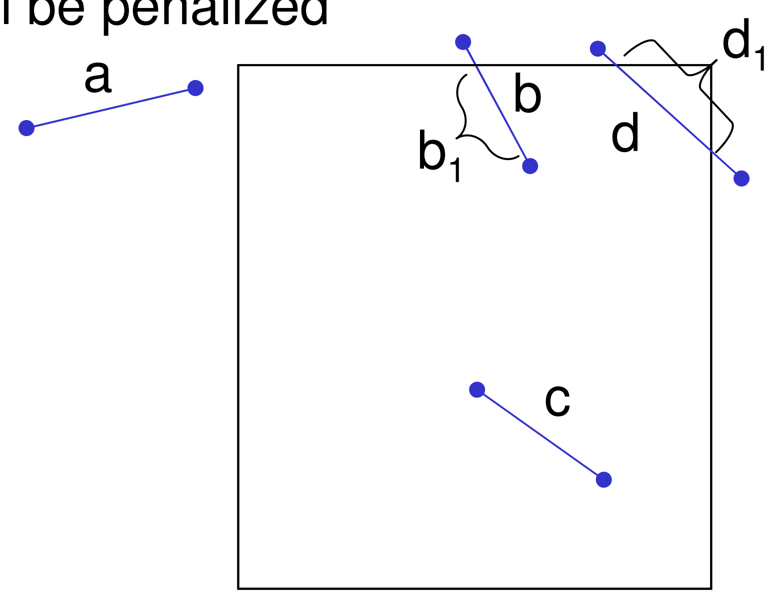
- Edge is penalized during the traffic jam only if it is traveled after noon and both end points are inside the traffic jam region

    a will not be penalized

    b_1 will be penalized

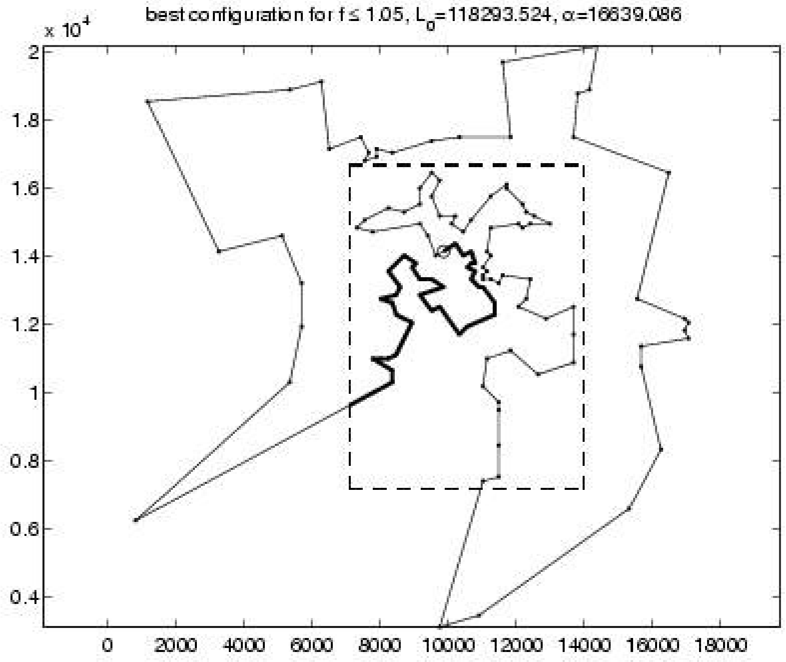
    c will be penalized

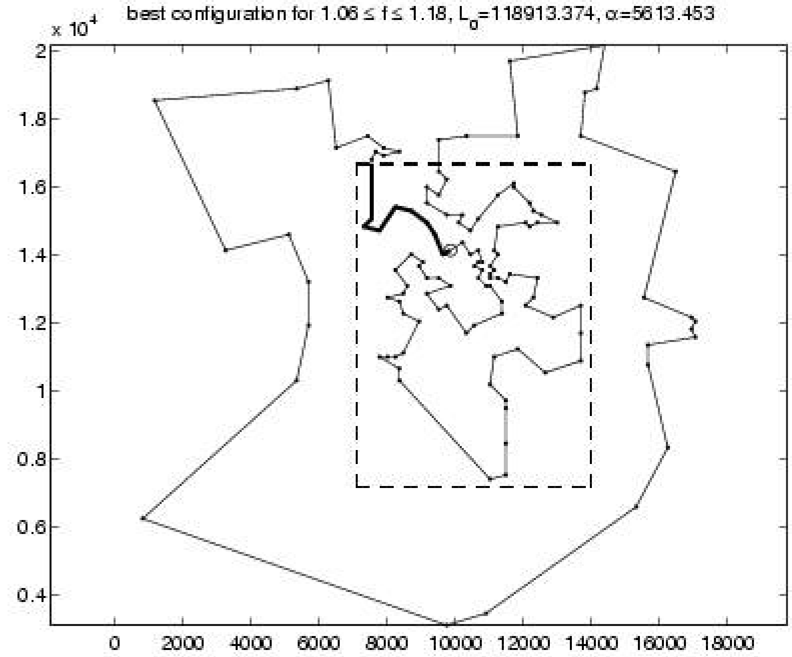
    d_1 will be penalized



New Assumption

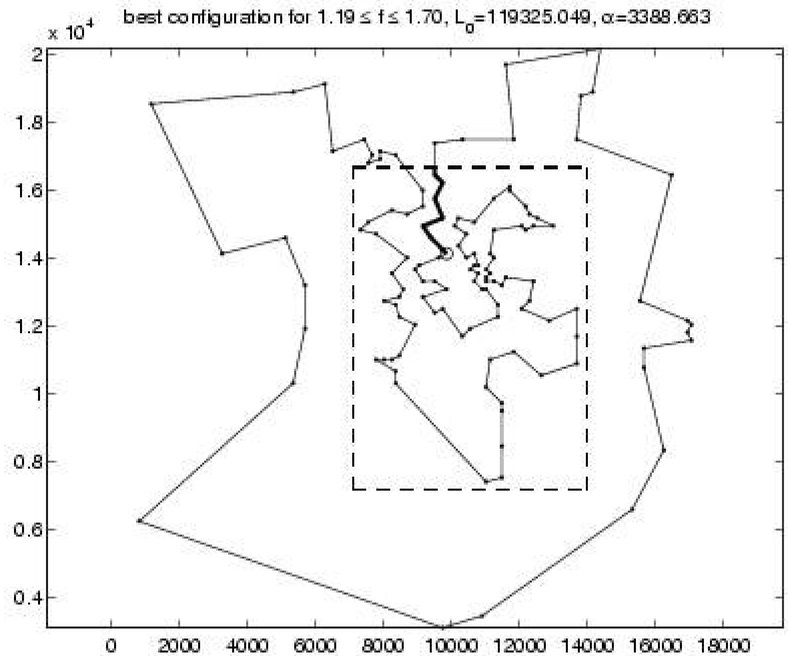
- Computational Results: CLK

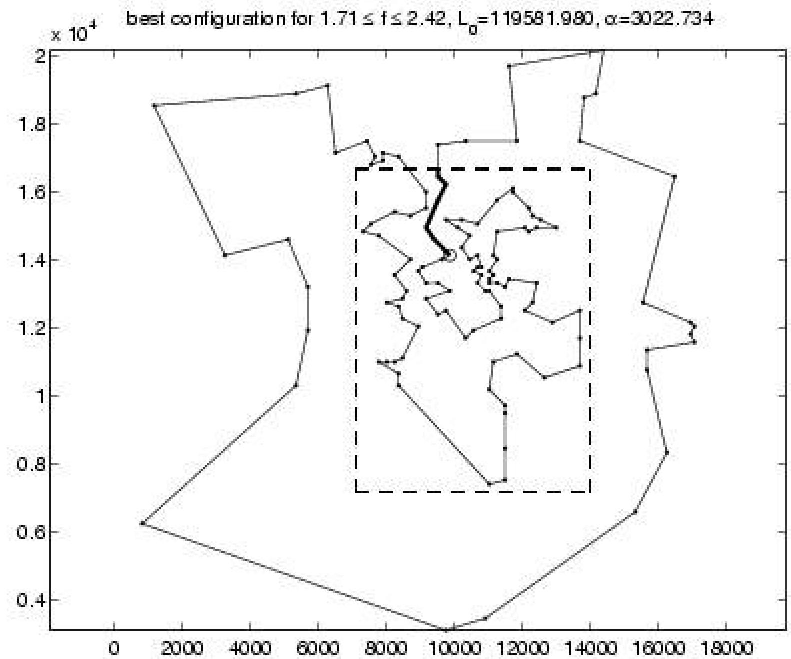




New Assumption

- Computational Results: CLK





New Assumption

- Computational Results: CLK

Jam Factor	Time	Tour Length	Percent Above Best Known	Best-known Solution
1.00	4.08	118293.524	0.00	118293.524
1.05	4.16	119125.478	0.00	119125.478
1.18	4.78	119923.796	0.00	119923.796
1.70	4.20	121697.112	0.00	121697.112
2.43	4.96	123901.699	0.00	123901.699
3.75	4.82	127518.019	0.00	127518.019
6.53	5.19	134916.352	0.04	134858.670

Objective Function

- For each configuration, the objective function has two parts

L_0= tour length of TSP

α = penalized arc length

$Obj = L_0 + \alpha\ (f\text{-}1)$

a linear function of jam factor f

- For all configurations, the objective function is the lower envelope of these lines

Objective Function

Boundary Intervals for the Jam Factor

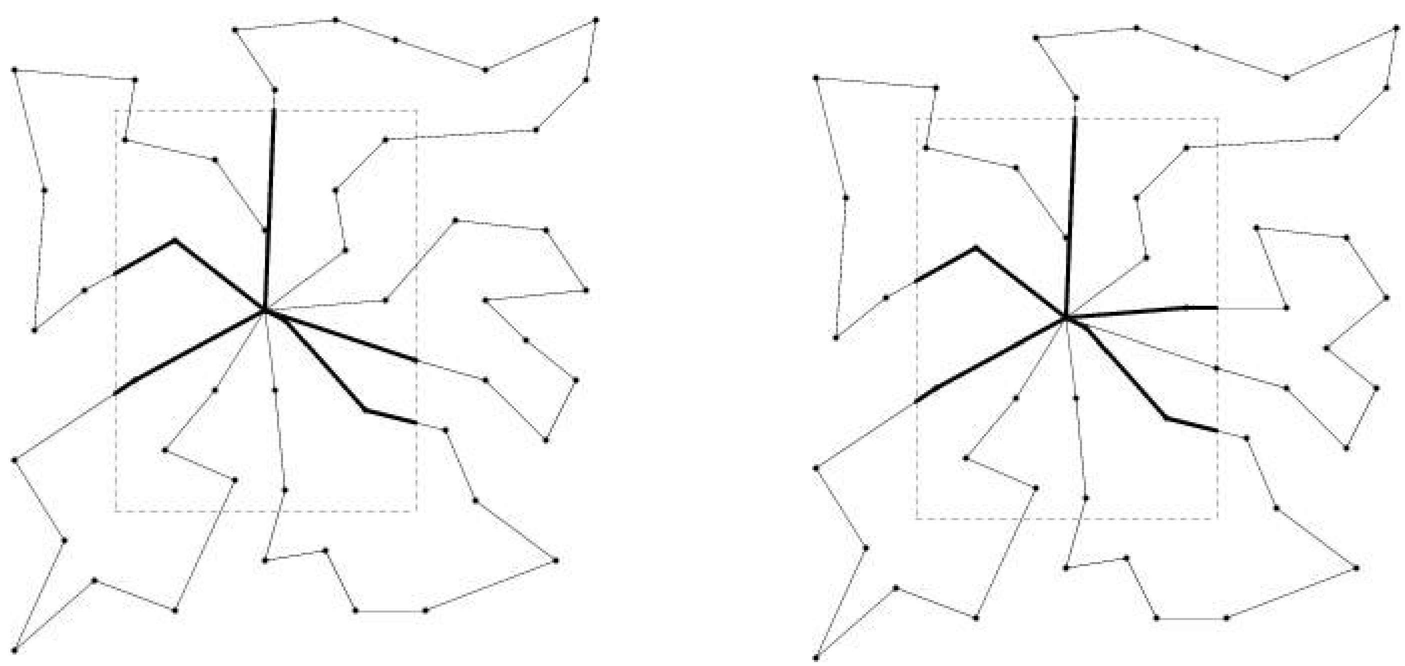
Boundary Intervals for Jam Factor f	L_0	α
[1.00, 1.05]	118293.524	16639.086
[1.06, 1.18]	118913.374	5613.453
[1.19, 1.70]	119325.049	3388.663
[1.71, 2.42]	119581.980	3022.734
[2.43, 3.74]	119983.542	2739.969
[3.75, 6.53]	120256.583	2640.522

Time Dependent Vehicle Routing Problem

- Introduce a traffic jam region into the VRP
  - Use the 50-node benchmark problem from Christofides et al. (1979)
  - Driver starts at 8 am and finishes at 5 pm
  - Use the maximum route length of the optimal VRP solution to estimate the travel speed
  - It is not necessary that a route fills the work day exactly
- Apply record-to-record travel with the new assumption

Time Dependent Vehicle Routing Problem

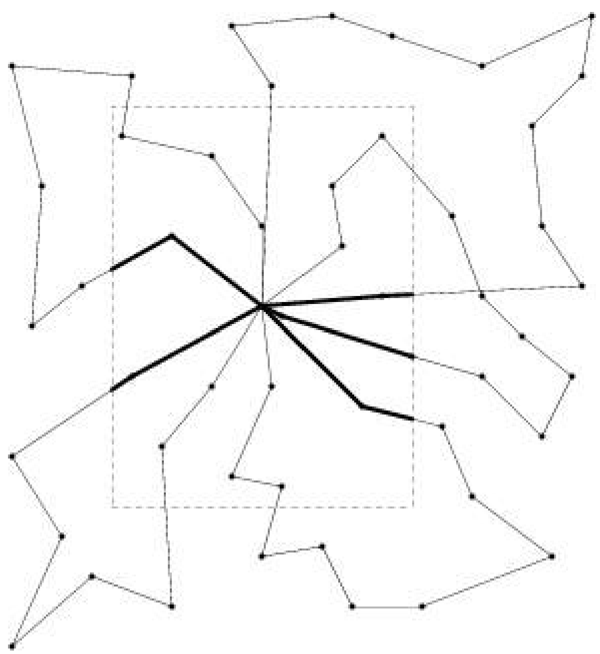
$f \leq 1.02$, $L_0 = 524.61$ $1.03 \leq f \leq 1.77$, $L_0 = 524.63$



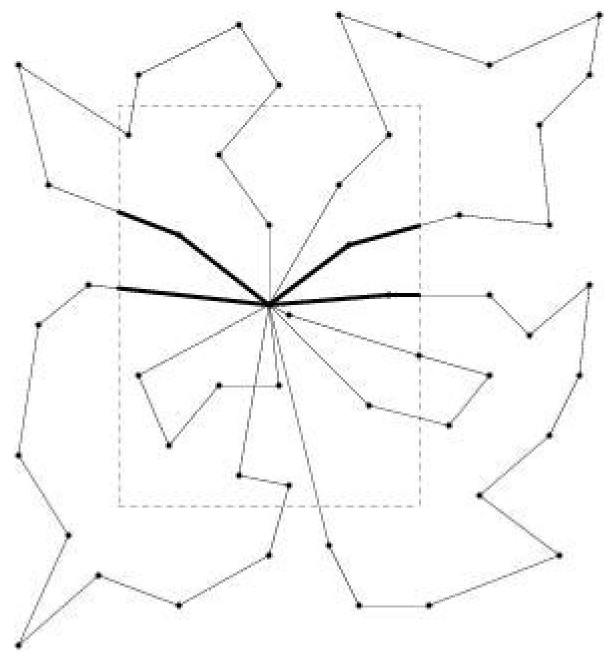
As f increases in value, fewer customers are serviced in the traffic jam region after noon (the bold edges are traveled after noon) and the value of L_0 increases

Time Dependent Vehicle Routing Problem

$1.78 \leq f \leq 2.27$, $L_0 = 527.98$



$2.28 \leq f \leq 3.75$, $L_0 = 553.88$



Conclusions

- We extended the time dependent TSP to include a realistic travel assumption and developed two solution algorithms (RTR, CLK) to solve it
- Our chained Lin-Kernighan approach was *fast* and produced *high-quality* results
- We extended the notion of time dependency to the vehicle routing problem