New Developments in the Computerized Routing of Meter Readers over Street Networks

by

Robert Shuttleworth, University of Maryland
Bruce Golden, University of Maryland
Edward Wasil, American University

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Outline of Lecture

- The close enough traveling salesman problem (CETSP)
- The CETSP over a street network
- Heuristics for solving this problem
  - Greedy Approaches
  - IP Formulations
- Conclusions

The Close Enough Traveling Salesman Problem

- Until recently, utility meter readers had to visit each customer location and read the meter at that site
- Now, radio frequency identification (RFID) technology allows the meter reader to get close to each customer and remotely read the meter
- Our models are based on data from a utility and use an actual road network with a central depot and a fixed radius r for the hand held device
- Our goal is to minimize distance traveled or elapsed time

The CETSP over a Street Network

- We used RouteSmart (RS) with ArcGIS
  - Real-world data and constraints
  - Address matching
  - Side-of-street level routing
  - Solved as an arc routing problem
- Our heuristic selects segments to exploit the "close enough" feature of RFID
- RS routes over the chosen segments to obtain a cycle
- Currently, RS solves the problem as a Chinese (or rural) Postman Problem

Heuristic Implementation

- How do we choose the street segments to feed into RS?
- We tested several ideas
- Greedy procedures
  - Greedy A: Choose the street segment that covers the most customers, remove those customers, and repeat until all customers are covered
  - Greedy B: Same as above, but order street segments based on the number of customers covered per unit length
- IP Formulations

IP Formulation

- We also experimented with formulating the problem as an IP:

$$\text{Minimize} \quad \sum_j c_j x_j$$

subject to

$$\sum_j a_{ij} x_j \geq 1 \text{ for all } i$$

$$x_j \in \{0,1\}$$

where $a_{ij} = 1$ if customer i is covered by road segment j

0 otherwise

and $x_j = 1$ if road segment j is traversed

0 otherwise

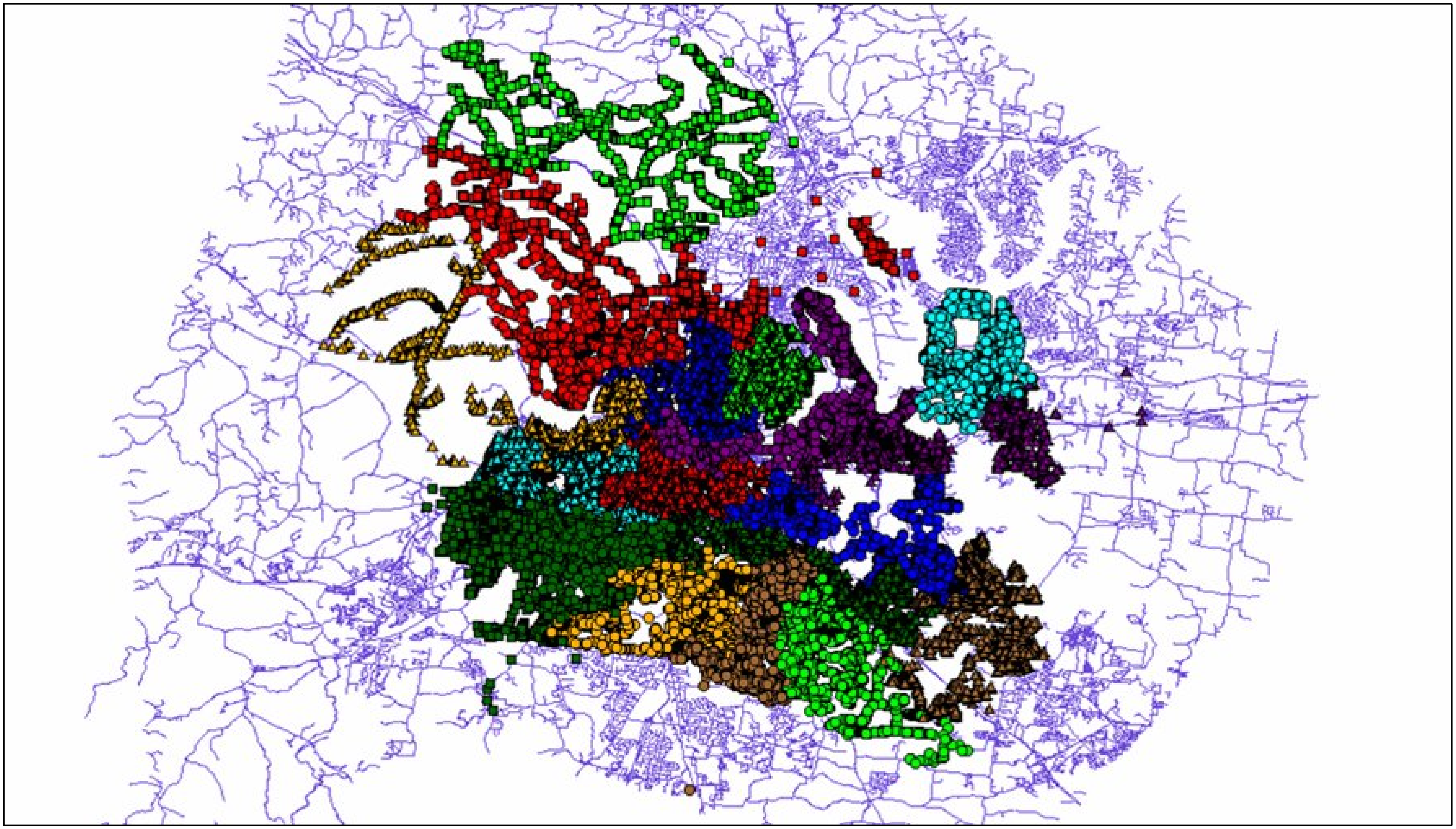
IP Variants

- How do we choose the street segments to feed into RS?
- We tested several choices for the objective function
  - IP1: Minimize the number of road segments chosen

    $c_j = 1$ for all j
  - IPD1: Minimize the distance of the road segments chosen

    c_j = the distance of road segment j

Each Color is a Separate Partition



A Single Partition

A Closer Look at a Partition

The Area Covered with RFID

The Area Covered by the Entire Partition

Dense Partition Results

		500 foot radius			
Method	Miles	Hours	Number of Segments	Miles of Segments	Deadhead Miles
RS	204.8	9:22	1099	97.5	107.3
Greedy A	160.5	7:06	470	64.4	96.1
Greedy B	166.5	7:27	577	64.2	102.3
IP1	165.8	7:25	458	62.4	103.4
IPD1	161.6	7:15	470	59.1	102.5
Essential	–	–	342	43.3	–

Dense Partition Results

		350 foot radius			
Method	Miles	Hours	Number of Segments	Miles of Segments	Deadhead Miles
RS	204.8	9:22	1099	97.5	107.3
Greedy A	171.9	7:45	621	78.1	93.8
Greedy B	179.3	7:55	610	78.0	101.3
IP1	169.8	7:39	608	77.6	92.2
IPD1	168.1	7:40	609	76.9	91.2
Essential	–	–	451	61.9	–

Sparse Partition Results

		500 foot radius			
Method	Miles	Hours	Number of Segments	Miles of Segments	Deadhead Miles
RS	213.6	9:26	405	98.4	115.2
Greedy A	189.9	8:22	217	79.6	110.3
Greedy B	197.0	8:56	236	84.7	112.3
IP1	188.2	8:18	216	78.5	109.7
IPD1	188.4	8:18	216	78.3	110.1
Essential	–	–	212	78.0	–

Sparse Partition Results

350 foot radius					
Method	Miles	Hours	Number of Segments	Miles of Segments	Deadhead Miles
RS	213.6	9:26	405	98.4	115.2
Greedy A	200.1	8:34	379	91.2	108.9
Greedy B	203.1	8:41	391	93.3	109.8
IP1	200.5	8:36	378	91.6	108.9
IPD1	201.0	8:37	380	91.0	110.0
Essential	–	–	325	85.9	–

Results for all 18 Partitions

500 foot radius					
Method	Miles	Hours	Number of Segments	Miles of Segments	Deadhead Miles
RS	3798.1	165:41	16509	1545.1	2253.0
Greedy A	3045.2	140:05	9895	1498.9	1546.3
Greedy B	3140.3	144:41	11483	1528.6	1611.7
IP1	3055.6	140:37	9857	1492.8	1562.8
IPD1	3039.1	140:02	9907	1491.8	1547.3
Essential	–	–	7777	1399.6	–

Results for all 18 Partitions

	500 foot radius			
			Best	Best
Method	Miles	Hours	Time	Distance
RS	3798.1	165:41	0	0
Greedy A	3045.2	140:05	7	7
Greedy B	3140.3	144:41	0	0
IP1	3055.6	140:37	4	5
IPD1	3039.1	140:02	7	8

Redundancy

- To provide redundancy, we test how serving each customer by at least two different road segments effects the costs
- In terms of the IP, change $\sum_j a_{ij} x_j \geq 1$ to $\sum_j a_{ij} x_j \geq 2$

500 foot radius					
Method	Miles	Hours	Number of Segments	Miles of Segments	Deadhead Miles
IP2	192.3	8:23	250	81.2	111.1
IPD2	193.1	8:26	251	79.9	113.2
IP1	188.2	8:18	216	78.5	109.7
IPD1	188.4	8:18	216	78.3	110.1

Conclusions

- We have shown several heuristics for solving this new class of problems
- The best heuristics seem to work well
- RFID travel paths have a 15% time savings and 20% distance savings over the RS solution
- As the technology improves (i.e., the radius increases) the savings will increase dramatically