# 1.224J Recitation #4

Freight transportation

# Topics

- Homework questions
- Home Depot
- MVRP: Multi vehicle routing problem
  - Applications
  - Formulation
  - Heuristics  (Clarke-Wright and Polar sweep)

# Homework

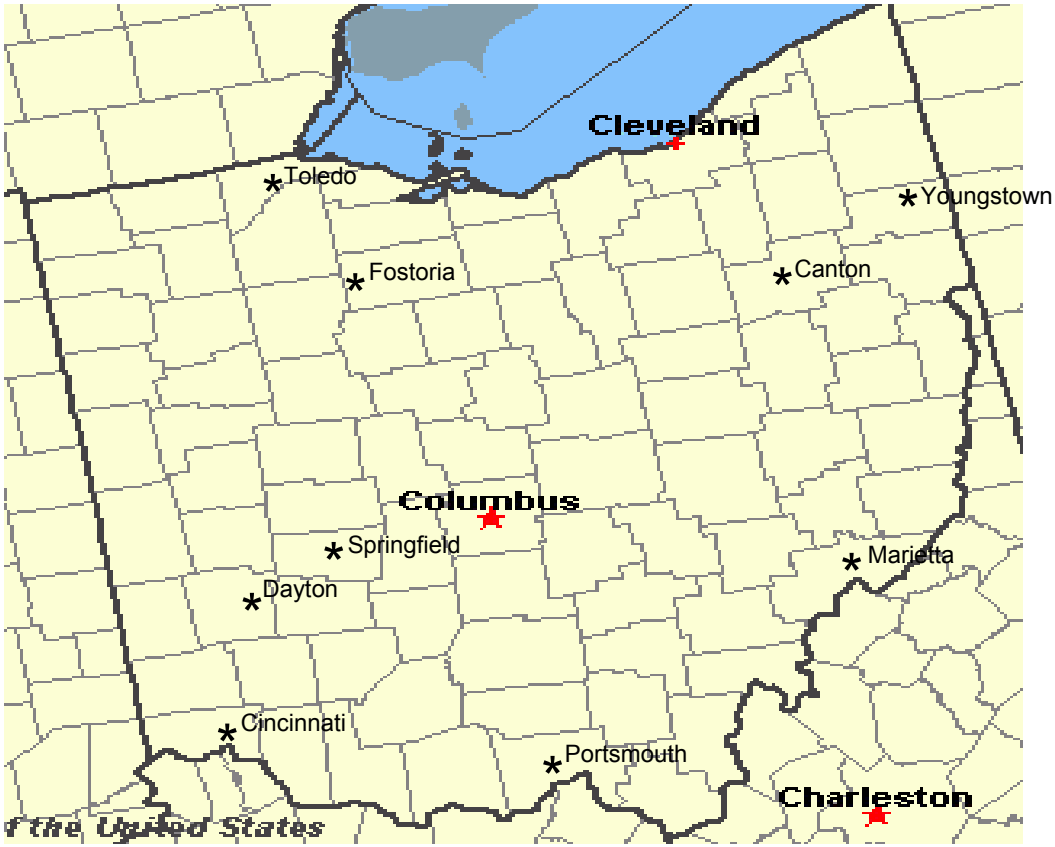
- Last week
  - PS 2 constraint formulations
  - No “IF” statements allowed!
  - Concave minimization example
- PS 3 and 4: Set covering and enumeration ideas

# Home Depot

- 1999: 7 million LTL loads, 220,000 TL
- Pre 1996: single lane bidding!
  - Very difficult for carriers.
- 1996-200, developed multi-lane bidding with i2. Implemented in 2000.

# MVRP: Multi vehicle routing problem

- Find lowest cost set of routes with constraints on vehicle capacity and vehicle travel times, while satisfying pickup or delivery requirements
- TSP comparison

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# Applications of MVRP

- Newspaper delivery
- Trash pickup
- National Blood Reserve
  - "The Red Cross is establishing a national blood reserve - a strategically located reserve supply of blood supported by a state-of-the-art logistics and distribution system." redcross.org

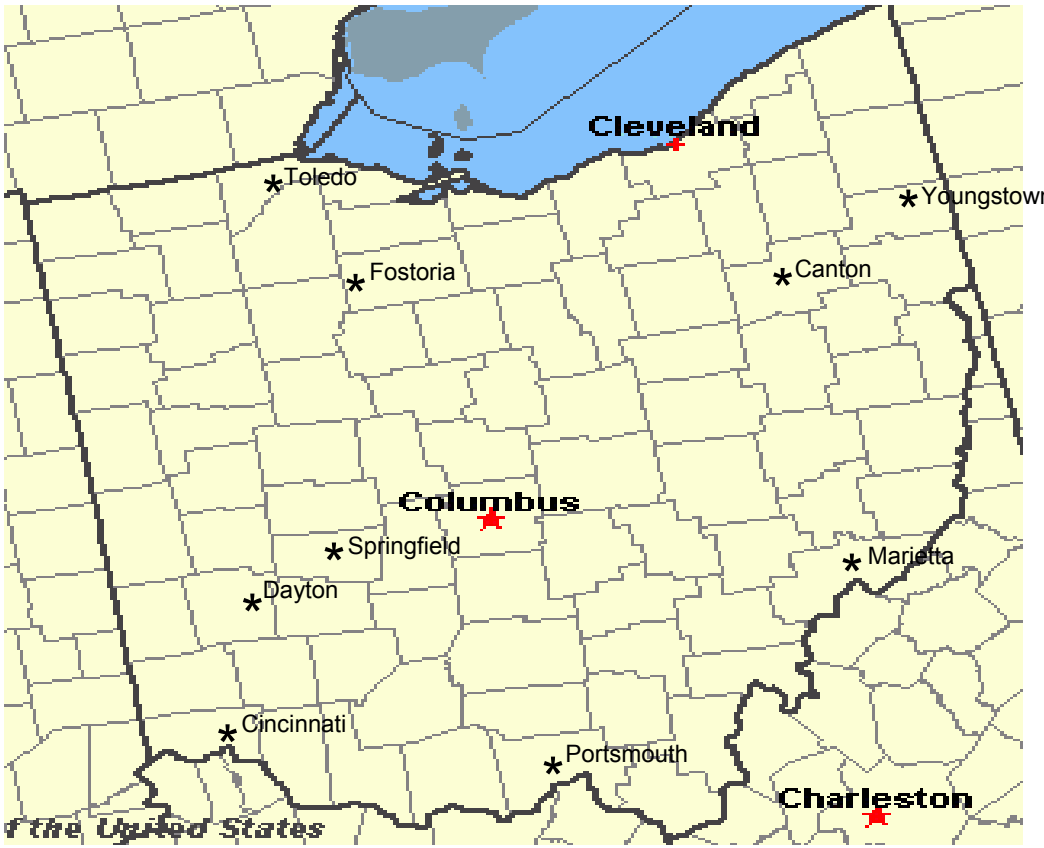
# Multiple Vehicle Scheduling

## MIP, Set Covering, Column Generation

| | Route 1 | Route 2 | Route 3 | …. | ….. | Route M | |
|---|---|---|---|---|---|---|---|
| | C1 | C2 | C3 | …. | …. | Cm | |
| Stop A | 1 | 0 | 0 | 1 | 0 | 1 | 1 |
| Stop B | 1 | 1 | 0 | 0 | 1 | 0 | 1 |
| Stop C | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| Stop D | 0 | 1 | 1 | 0 | 1 | 1 | 1 |
| Stop E | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| Stop F | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Stop G | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| … | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| .. | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Stop N | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

- Each Row represents one of the N stops
- Each Column represents a generated vehicle route and its cost
- Each matrix coefficient, $a_{ij}$, is {0,1}, identifying the stops on the j'th route
- Define $Z_{ij}$, {0,1}, "1" if Stop "i" is on Route "j" , else "0"
- Define $Y_j$, {0,1}, "1" if the sum of $Z_{ij}$ >0 , i=1,n ; else "0"
- Minimize: the sum of $C_j Y_j$, , j=1,m
- Subject to: the sum of $a_{ij}$ $Z_{ij}$ =1, j=1,m; for all i

# Optimal Routing Solution

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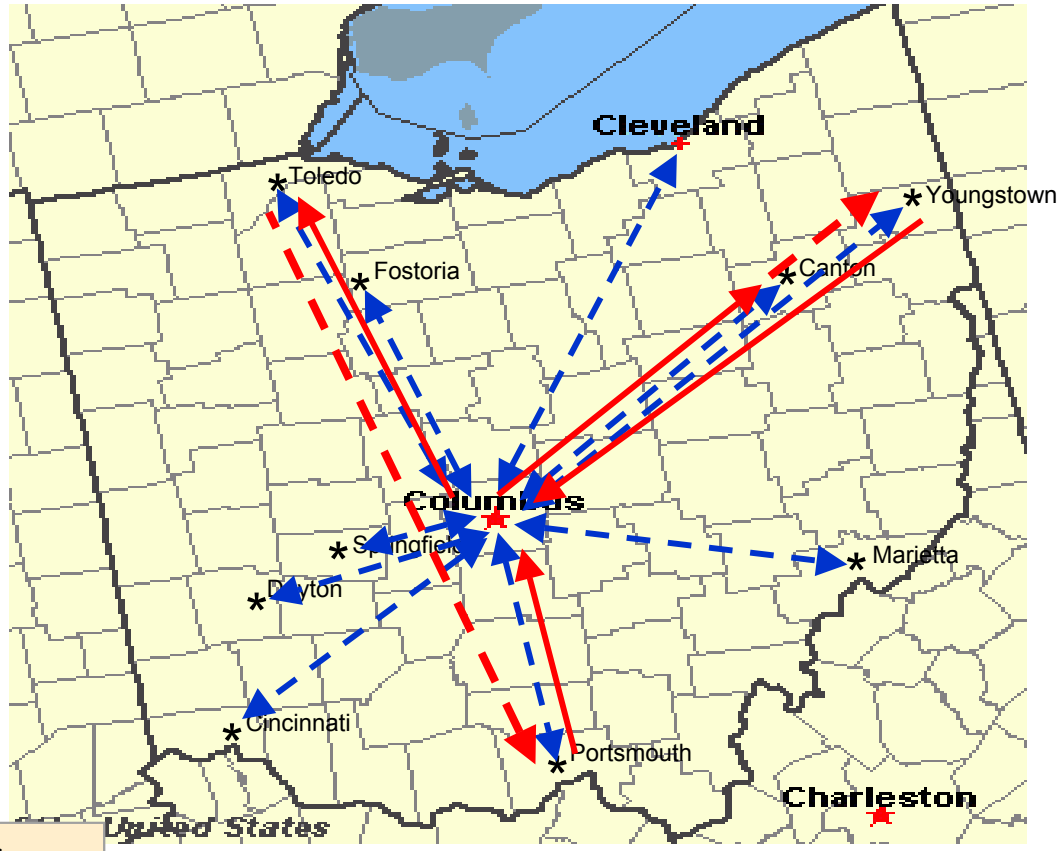
# Heuristic Approach – Savings

**Clarke-Wright "savings" algorithm, 1964**

1. Serve each stop with direct out and back
2. Find savings for each pair

   $S=D_{OA}+D_{OB}-D_{AB}$
3. Combine loads that increase savings and $<V_{MAX}$

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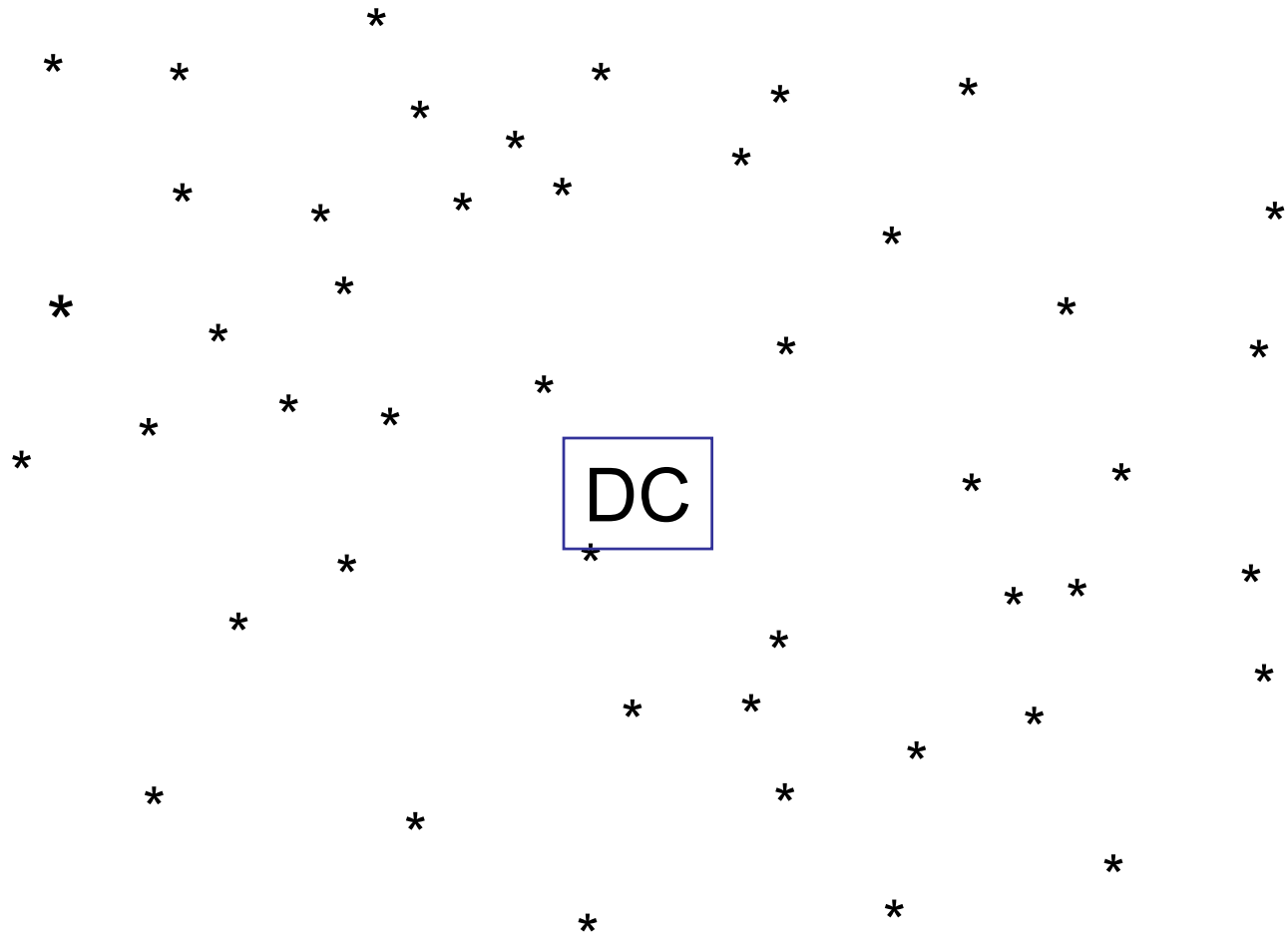
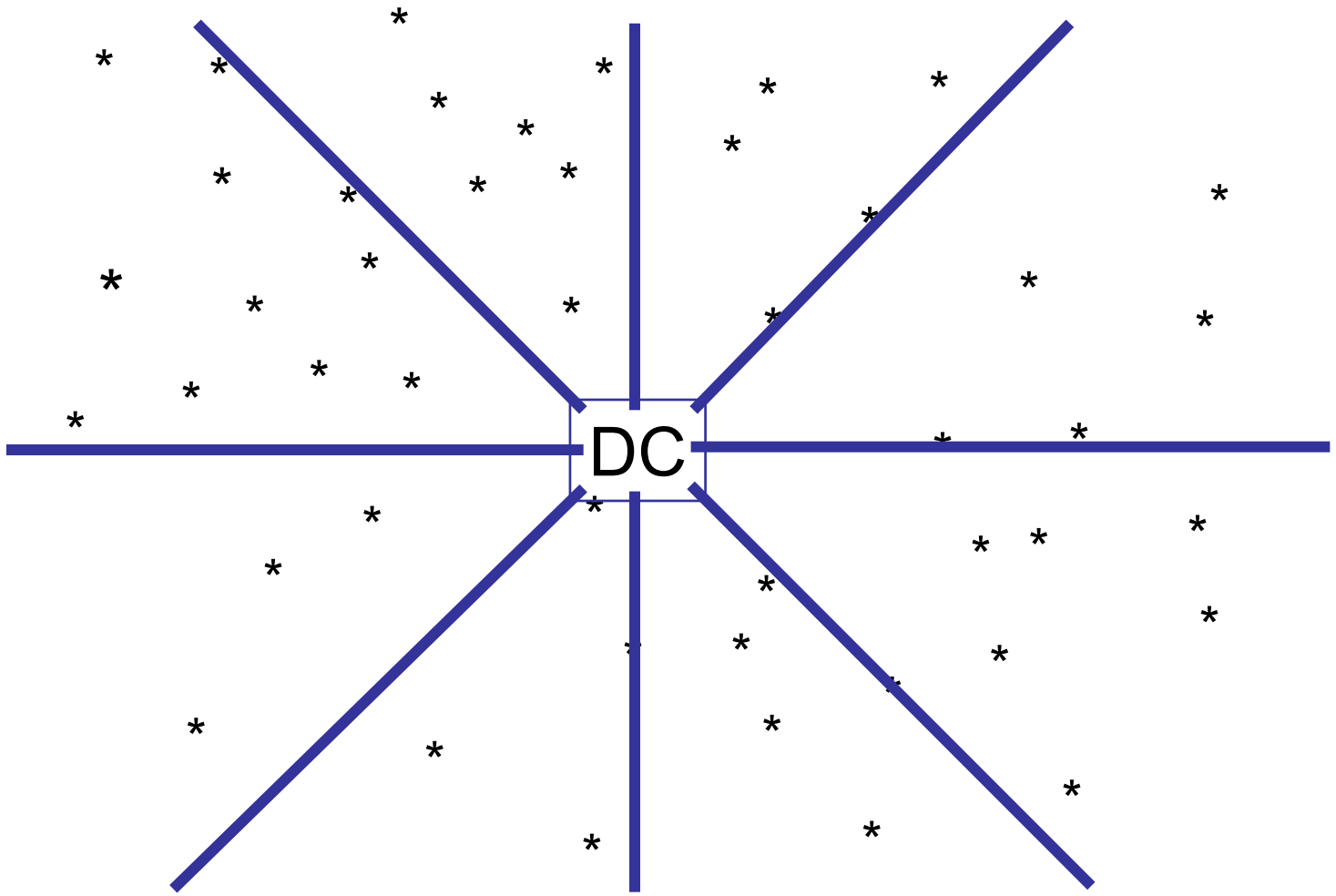
# Heuristic Approach – Polar Sweep,

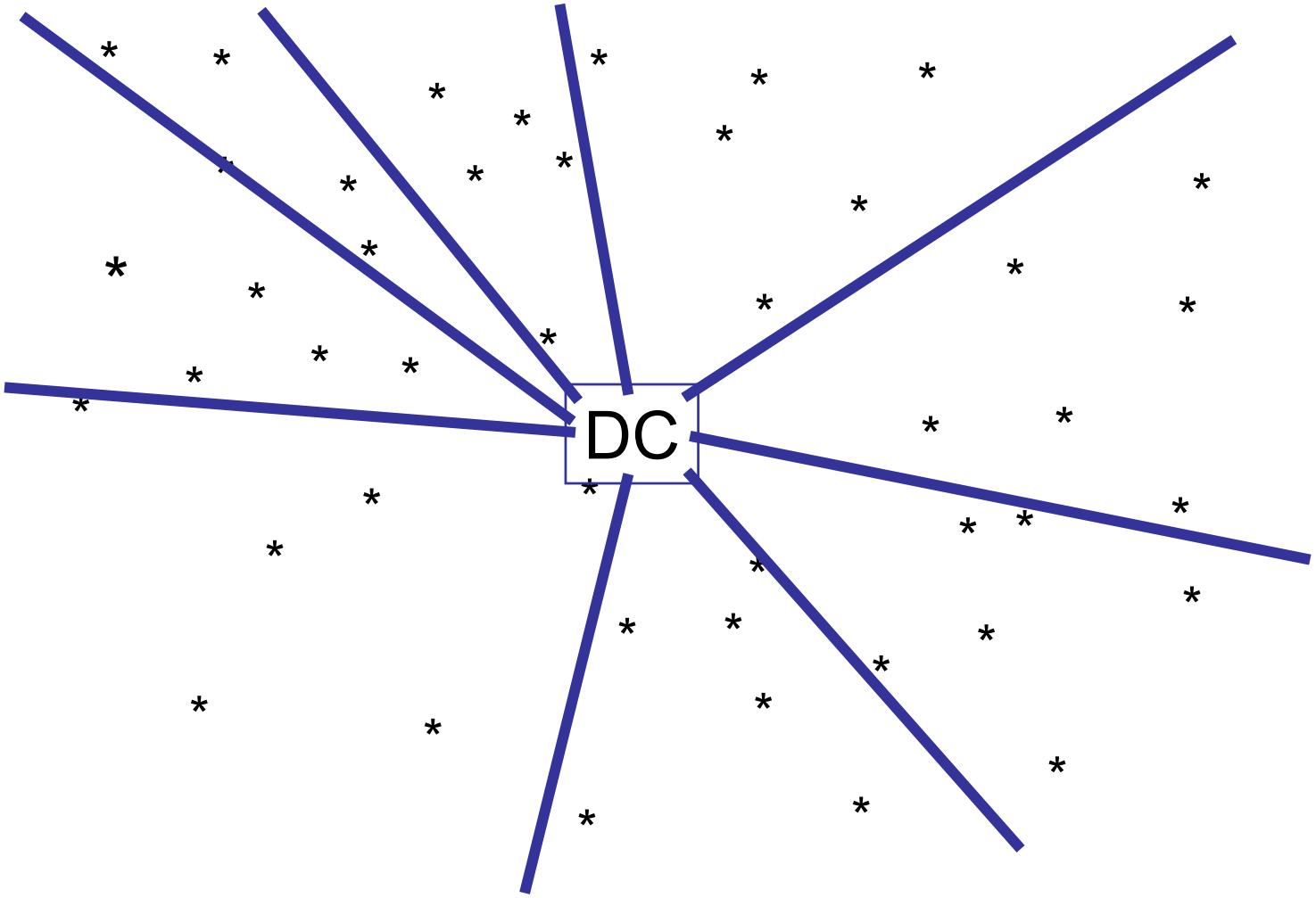
Gillett and Miller 1974



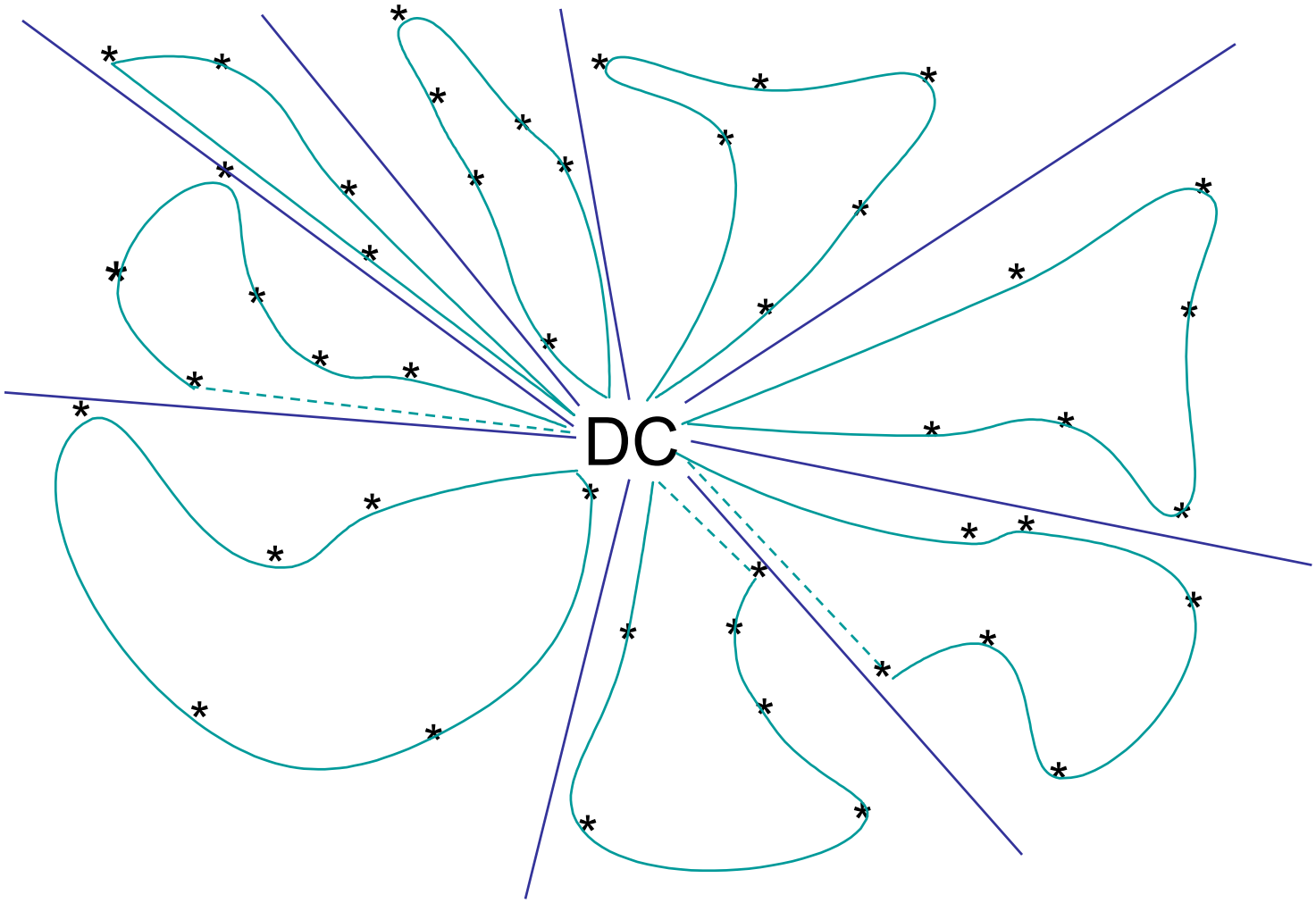
# Polar sweep



# Sweep until filled up…



# Then solve a bunch of TSPs



# Clarke-Wright and Polar sweep demos