Schietzelt, T. H. and Densham, P. J. 2003.

Location-allocation in GIS

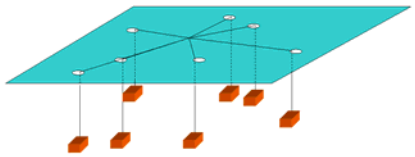
GIS Applications

Use of analytical GIS tools to:

- Describe
- Explain
- Predict
- Support decision-making
  - Prescribe (i.e., prescriptive or normative use of GIS)

Location-Allocation

- 1) Where to **locate** and 2) how to **allocate** demand for service to the central facility.
- Point of minimum aggregate travel (MAT)
- Varignon



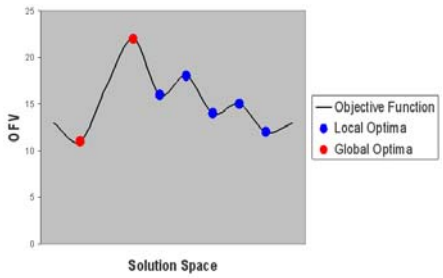
1-median problem

p-medium Problem

- To find optimum locations of p facilities such that the sum of the (weighted) distance between each demand location and the nearest facility is minimized.

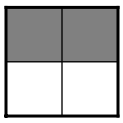
Optimization

- Finding the best solutions to a problem
- Operations research
- Considerations:
  - Single and multi-objective problems
  - Static or dynamic
  - Constraints (capacitated)
  - Objective function



Combinatorial Optimization

- Problem: find the pattern that produces the longest perimeter in a 2 by 2 gridded landscape with 2 foreground cells (black) and 2 background cells (white).
- How many different patterns (solutions) are there?
- ${}_4C_2 = (4*3)/(1*2) = 6$



Solving p-medium

- Combinatorial optimization
  - Seeking the best combination of demand locations allocated to p facilities.
- Complete enumeration
- “Hard” problems (NP-Hard)

$$_{100}C_{50} = \frac{100!}{50! \times (100-50)!} > 10^{29}$$

(i.e. if a computer can generate 100M solutions/sec, then it takes 100B centuries to finish.)

Solution Methods

- Exact (based on math equations)
  - Integer linear programming
  - Branch and bound
  - Lagrange relaxation
- Basic heuristics (iterative trial and error)
  - ADD, Drop
  - Global Regional Interchange Algorithm (GRIA)
  - Swapping (n-opt)
  - Greedy (uphill-climbing) method
- Advance heuristics (iterative trial and error)
  - e.g., Simulated annealing

GRIA (Global Regional Interchange Algorithm)

- GRIA begins with a 'starting solution', or 'seed', of m candidates. The algorithm then goes through a global phase and a regional phase of candidate substitutions.
- Global phase
  - a site is selected that makes the least increase in the total weighted distance once it is removed from the solution. It is replaced with the candidate that decreases the total weighted distance the most. These substitutions are done until there is no further reduction in the total weighted distance.
- Regional phase
  - involves looking at the candidates allocated to each site. If a site can be replaced by one of these candidates to reduce the total weighted distance, the substitution is made. These substitutions are done until there is no further reduction in the total weighted distance.

Location-Allocation in ArcInfo

- You need a network coverage (e.g., **roads**) containing a route (e.g., **routes**), a point coverage of demands (e.g., **demandpts**), and a list of candidate locations (e.g., **roads.cen**)
- The AAT of the network coverage should have an attribute field indicating the cost of travel (or impedance) (e.g., length)
- The PAT of point coverage should have an attribute field indicating the number of demands (e.g., popu)
- The following commands find 3 nodes on the network as supply centers

```
Arc: w c:\Users\Myworkspace
Arc: arcplot
Arcplot: disp 9999
Arcplot: mape roads
Arcplot: arcs roads
Arcplot: nodes roads
Arcplot: pointmarkers demandpts 4      /* 4 is the symbol of a blue cross
Arcplot: netcover roads routes
Arcplot: impedance length
Arcplot: centers roads.cen
Arcplot: locatecandidate CENTERS
Arcplot: locatecandidate demandpts POINT popu
Arcplot: locateallocate outalloc outcenters outglob 3
Arcplot: show locateallocate
```

- Use ARCROUTE command to create a route.

Measuring Distance (Accessibility)

- Euclidian distance
- Cost-distance (accessibility)
- Cost function
  - Determined by distance
  - Linear or non-linear
  - Deterministic constant or stochastic random variable

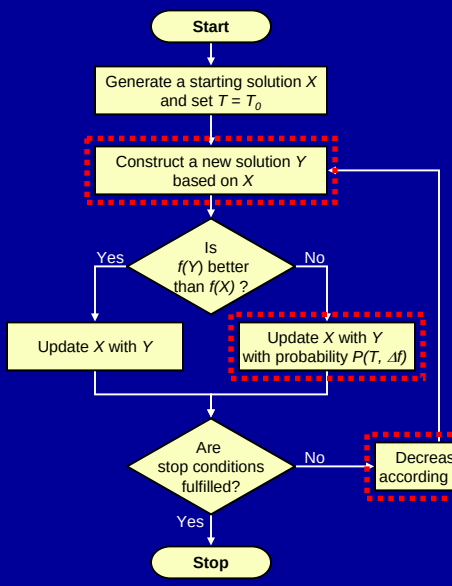
Location-Allocation Example (Emergency Medical Services)

- Demands
  - Single / multi-supply
  - Dynamic
- Supplies
  - Capacitated / non-capacitated
- Cost-function
  - Network distance
  - Congestion/delay

Meta-Heuristic Methods

- Won't guarantee finding global optima
- Different initial solutions result in different final solutions
- Two phases search
  - Explore
  - Exploit

Simulated annealing



Perturbation Rules (Operators):
- Random
- Preferential

Probability of accepting inferior solutions

$$P(T, \Delta f) \approx 1 - \exp(-\Delta f / T)$$

$$\Delta f = ABS(f(y) - f(x))$$

$$\exp(0) = 1,\ \exp(-\infty) = 0$$

Cooling schedules:
- Temperature = f(Annealing Time)

$$T(k) = \frac{T_0}{\ln k} \quad k > 1$$