
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-median 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?
• \( _4C_2 = \frac{(4*3)}{(1*2)} = 6 \)
Solving p-medium

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

\[ \binom{100}{50} = \frac{100!}{50!(100-50)!} > 10^{29} \]  
(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
Example

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.
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
Location-Allocation in ArcGIS 10

• You need:
  – Network Analyst extension
  – A network dataset
  – A demand-points feature class
  – A candidate facilities feature class

Use Catalog network wizard to create a network from a street layer
A network with edges and junctions…

Prepare demand points and candidate locations, load them to the Network Analyst …

- I used the network junctions to create the demand points and candidate facility locations
Ready to solve the location-allocation problems…

## Location-Allocation Problem Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize Impedance (P-Median)</td>
<td>Facilities are located such that the sum of all weighted costs between demand points and solution facilities is minimized.</td>
<td>Locate warehouses</td>
</tr>
<tr>
<td>Maximize Coverage</td>
<td>Facilities are located such that as many demand points as possible are allocated to solution facilities within the impedance cutoff.</td>
<td>Locate fire stations</td>
</tr>
<tr>
<td>Minimize Facilities</td>
<td>Facilities are located such that as many demand points as possible are allocated to solution facilities within the impedance cutoff; additionally, the number of facilities required to cover demand points is minimized.</td>
<td>Locate fire stations without budget limit</td>
</tr>
<tr>
<td>Maximize Attendance</td>
<td>Facilities are chosen such that as much demand weight as possible is allocated to facilities.</td>
<td>Locate stores without competitors</td>
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<tr>
<td>Maximize Market Share</td>
<td>A specific number of facilities are chosen such that the allocated demand is maximized in the presence of competitors.</td>
<td>Locate store with competitors</td>
</tr>
<tr>
<td>Target Market Share</td>
<td>Target Market Share chooses the minimum number of facilities necessary to capture a specific percentage of the total market share in the presence of competitors.</td>
<td>Locate store with competitors but without budget limit</td>
</tr>
</tbody>
</table>
Solution: Minimizing impedance with 4 facilities

ESRI BAO (Business Analyst Online)
• http://www.esri.com/software/bao/index.html