Geography 12: Maps and Mapping

Lecture 20: Applications of Feature Measurements

Measurement

- Shape
  - Miller
  - Bunge
  - Boyce-Clark
  - Fourier measures

- Distribution
  - Quadrat analysis
  - Nearest neighbor analysis
To evaluate the geographic distribution by residence at the time of illness, cases from 1978 to 1981 within Miami-Dade County, a ciguatera endemic region, were analyzed (Figure 1). Of the 304 index cases, 169 occurred in Miami-Dade County, with 102 (60.4% of Miami-Dade County cases) of these cases occurring during the specified time period. A nearest-neighbor analysis was performed in an attempt to show a random distribution of cases in the county. However, despite various attempts to adjust for population density and lack of habitability (e.g., airports, Everglades, and ocean areas), the R-value was 0.10, indicating a strong clustering pattern. Nevertheless, the clustering pattern closely followed densely populated roadways that pass through highly varied neighborhoods.

Nearest-Neighbor Analysis

- Unlike quadrat analysis uses distances between points as its basis
- The mean of the distance observed between each point and its nearest neighbor is compared with the expected mean distance that would occur if the distribution were random
- Also needs a reference area
RANDOM UNIFORM CLUSTERED

Point Nearest Neighbour Distance
1 2 1
2 3 0.1
3 2 0.1
4 5 1
5 4 1
6 5 2
7 6 2.7
8 10 1
9 10 1
10 9 1

Area of Region 50
Density 0.2
Expected Mean 1.118034
R 0.9749256

RANDOM UNIFORM CLUSTERED

Point Nearest Neighbour Distance
1 3 2.2
2 4 2.2
3 4 2.2
4 5 2.2
5 7 2.2
6 7 2.2
7 8 2.2
8 9 2.2
9 10 2.2
10 9 2.2

Area of Region 50
Density 0.2
Expected Mean 1.118034
R 1.9677398

CLUSTERED

Point Nearest Neighbour Distance
1 2 0.1
2 3 0.1
3 2 0.1
4 5 0.1
5 4 0.1
6 5 0.1
7 6 0.1
8 9 0.1
9 10 0.1
10 9 0.1

Area of Region 50
Density 0.2
Expected Mean 1.118034
R 0.0894427

\[ NNS = 2 \times \frac{\sum d_i}{npts \times \sqrt{A/npts}} \]
Advantages of Nearest Neighbor over Quadrat Analysis

• No quadrat size problem to be concerned with
• Takes distance into account
• Problems
  – Related to the entire boundary size
  – Must consider how to measure the boundary
    • Arbitrary or some natural boundary
  – May not consider a possible adjacent boundary

NNS problems

\[ NNS = 0.1 \quad NNS = 1.0 \quad NNS = 2.0 \quad NNS = 2.14 \]

\[ NNS = 1.0 \quad NNS = \text{clustered or random?} \]
Scaling patterns

Measurement

• Spatial Correspondence
  – Coefficient of areal correspondence
  – Chi-square
  – Yule’s Q
Compare over time, scale, theme, etc.

Overlay

© New Nodes Added
Example Test of Spatial Pattern

- Is there a relationship between the distribution of rainfall and the wheat yield in the area shown?
- NULL HYPOTHESIS: There is no relationship
- ALTERNATIVE HYPOTHESIS: There is a relationship
Chi-square

- Make assumption that there is no relation between maps A and B
- Compute statistics that allow the assumption to be rejected
- Chi-square is the sum of the (Observed value – Expected value)^2/Expected value
- Can check value against table for actual likelihoods

Calculating Chi-Squared : text p193

<table>
<thead>
<tr>
<th>Observed frequencies</th>
<th>High</th>
<th>Low</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right: Wheat Yield</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below: Rainfall</td>
<td>High</td>
<td>Low</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Low</td>
<td>5</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>15</td>
<td>28</td>
</tr>
</tbody>
</table>
Calculating Chi-Squared: text p193

Expected frequencies

<table>
<thead>
<tr>
<th>Right: Wheat Yield</th>
<th>High</th>
<th>Low</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below: Rainfall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>(35.7%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>8</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>(64.3%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>15</td>
<td>28</td>
</tr>
</tbody>
</table>

Chi-squared

\[
\text{Chi-square} = \sum \frac{(O-E)^2}{E}
\]

For the example = 5.625

This value is then compared to a table of chi-squared to see if the value allows us to reject the null hypothesis that the observed values are not those expected based on proportions.
Chi-squared tables

Two by two table has four values so three degrees of freedom

Chi-squared of zero is no relationship.
Higher the value the stronger the relationship.

<table>
<thead>
<tr>
<th>ν</th>
<th>0.995</th>
<th>0.990</th>
<th>0.975</th>
<th>0.950</th>
<th>0.900</th>
<th>0.100</th>
<th>0.050</th>
<th>0.025</th>
<th>0.010</th>
<th>0.005</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000</td>
<td>0.000</td>
<td>0.001</td>
<td>0.004</td>
<td>0.016</td>
<td>2.703</td>
<td>3.841</td>
<td>5.024</td>
<td>6.635</td>
<td>7.879</td>
</tr>
<tr>
<td>2</td>
<td>0.010</td>
<td>0.020</td>
<td>0.051</td>
<td>0.103</td>
<td>0.202</td>
<td>4.605</td>
<td>5.991</td>
<td>7.378</td>
<td>9.210</td>
<td>10.597</td>
</tr>
<tr>
<td>3</td>
<td>0.072</td>
<td>0.115</td>
<td>0.216</td>
<td>0.352</td>
<td>0.584</td>
<td>6.251</td>
<td>7.815</td>
<td>9.348</td>
<td>11.345</td>
<td>12.838</td>
</tr>
<tr>
<td>4</td>
<td>0.207</td>
<td>0.297</td>
<td>0.484</td>
<td>0.711</td>
<td>1.064</td>
<td>7.779</td>
<td>9.488</td>
<td>11.143</td>
<td>13.277</td>
<td>14.860</td>
</tr>
<tr>
<td>5</td>
<td>0.412</td>
<td>0.554</td>
<td>0.831</td>
<td>1.145</td>
<td>1.610</td>
<td>9.236</td>
<td>11.070</td>
<td>12.832</td>
<td>15.086</td>
<td>16.750</td>
</tr>
<tr>
<td>6</td>
<td>0.676</td>
<td>0.872</td>
<td>1.237</td>
<td>1.635</td>
<td>2.204</td>
<td>10.645</td>
<td>12.592</td>
<td>14.449</td>
<td>16.812</td>
<td>18.548</td>
</tr>
<tr>
<td>7</td>
<td>0.989</td>
<td>1.239</td>
<td>1.690</td>
<td>2.167</td>
<td>2.833</td>
<td>12.017</td>
<td>14.067</td>
<td>16.013</td>
<td>18.475</td>
<td>20.278</td>
</tr>
</tbody>
</table>


Yule’s Q

- Divide world into high/low (2 classes)
- Overlay two maps gives four classes
- Count quadrats in the four classes in a 2 x 2 table (with cells a,b,c,d) (i.e. Observed only)
- $Q = \frac{(ad - bc)}{(ad + bc)}$
- Value lies between -1 and +1
- -1 is perfect inverse relationship, +1 is perfect positive
Calculating Yule’s Q: text p193

Observed frequencies

<table>
<thead>
<tr>
<th>Right: Wheat Yield</th>
<th>High</th>
<th>Low</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>8 (a)</td>
<td>2 (b)</td>
<td>10</td>
</tr>
<tr>
<td>Low</td>
<td>5 (c)</td>
<td>13 (d)</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>15</td>
<td>28</td>
</tr>
</tbody>
</table>

Calculating Q

- Q = \( \frac{ad - bc}{ad + bc} \)
- \( (8 \times 13) - (2 \times 5) \)
- \( \frac{94}{114} = 0.82 \)
- \( (8 \times 13) + (2 \times 5) \)

Close to +1, so can conclude that there is a positive relationship
Testing spatial relationships

- Is there a relationship between geographical location and the price of gas?
- Are grocery store prices higher in poorer areas?
- Are the increased cancer death rates in a district caused by water contamination?
- Is there a relationship between hydrocarbon emissions and decreased upper atmosphere ozone in the polar regions?

Summary

- Distributions can be quantified, using NNS or other means
- Maps can be compared using Chi-squared, Yule’s Q etc.
- Allows cartometry of higher order structures on maps: shape, distribution, arrangement and pattern