Visualising Crime Clusters in a Space-time Cube

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1. Introduction

2. Space-time cube
3. Space-time kernel density
4. Space-time scan statistics
5. Comparison and combined approach
6. Conclusion

Aim

To examine the possibilities of 3D mapping of crime concentrations (so-called hotspots/clusters) in space and time with the aid of spatio-temporal statistical analysis.

(1) 3D kernel mapping + volume rendering
(2) Space-time scan statistics

Case study: snatch-and-run offences in Kyoto City
1855 crime occurrence points of snatch-and-run offences reported to the Kyoto Prefectural Police, 2003-4

Snatch-and-run offence

Typical on-road crime that has worsen general perceived safety in Japan.

Moving hotspots

- Crime mapping is used to identify geographic concentrations of crime, so-called hotspots.
- Crime hotspots are often recognised as moving objects.
  - "Displacement": dislocation of crime occurrence caused by local crime preventive activities.

A conventional way to see moving hotspots is comparisons of 2D crime maps at different time periods.

Difficult to understand temporal durations & geographical extents of crime hotspots, simultaneously
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Space-time cube

- Diagram for Time Geography
  - Horizontal axes: geographic dimensions
  - Vertical axis: time dimension

Space-time 3D kernel density mapping

Calculate density inside the cylindrical kernel at every gridded points in a space-time cube:

\[ f(x, y, t) = \frac{1}{nkh} \sum K_i \left( \frac{x-x_i}{h_x}, \frac{y-y_i}{h_y}, \frac{t-t_i}{h_t} \right) \]

Brunsdon et al. 2007

where \( K \) is Epaneknikov function

Volume rendering of space-time kernel density

VR: Degree of transparency is controlled to be higher for lower density regions. (Levoy, 1988)

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Space-time scan statistics
Automated search for significant high density cylindrical regions by moving cylindrical windows of different sizes

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Comparison

<table>
<thead>
<tr>
<th></th>
<th>3D kernel density</th>
<th>Space-time scan statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical test</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Images of cluster</td>
<td>Fuzzy</td>
<td>Clear-cut</td>
</tr>
<tr>
<td>Geometry of cluster</td>
<td>No restriction</td>
<td>Space-time cylinder</td>
</tr>
<tr>
<td>Transition of density within a cluster</td>
<td>Available</td>
<td>Lost</td>
</tr>
</tbody>
</table>

Alternating occurrence of crime clusters in a pair of cluster-regions

Temporal correlations of monthly crime incidence between hotspots regions

Both methods show the same general tendency of crime hot spots consisting of constant (pillars) and temporal clusters.
New Kind of Displacement?

- The level of local police activities increase soon after crime concentrations are recognised.
- Offenders may change their target region for committing crimes to avoid such local police activities.
- However, acquiring local knowledge of a different region would be expensive for the offenders.
- The level of local police activities decrease after a certain period. (The danger past and God forgotten)
- Thus, it would be reasonable for offenders to target known geographic regions alternately with a sufficient time interval.

Conclusions

1. We proposed 3D crime mapping in a space-time cube with the aid of space-time statistical analysis techniques.
   - 3D kernel mapping + volume rendering
   - Space-time scan statistics
2. The approach enables effective visualisation of the geographical extent and duration of crime hotspots simultaneously.
3. An empirical analysis of the snatch-and-run offences dataset of Kyoto City suggests ‘displacement’ phenomenon. It indicate the necessity of crime preventive actions in a widespread space-time context.

Acknowledgment

Thank you

Special thanks to the Department of Crime Analysis of the Kyoto Prefectural Police for providing the dataset for this study.

ArcGIS(ArcScene) tool of space-time kernel density is under development.