How Spatial Epidemiology Helps Understand Infectious Human Disease Transmission

Introduction

- **Infectious diseases** can be transmitted:
  - **Directly** (e.g., influenza)
  - **Indirectly** (e.g., through water, soil)
- **Spatial dimensions** are crucial for understanding and managing diseases.
- Advancements in **computing and statistical methods** enhance disease visualization and analysis.

Figure 1: Visualization of spatial dimensions in disease spread.

Spatial Data Types

- **Point Data**:
  - Raw data such as incidences, deaths, physical locations (e.g., hospitals)
- **Aggregate Data**:
  - Summaries of individual points like incidence rates by area
- **Point Data** provides detailed and precise information, allowing for pinpointing specific outbreak locations.
- **Aggregate Data** helps in understanding broader trends but can obscure local variations.

Disease Mapping Techniques

Location Mapping

- Historical examples:
  - Yellow fever in New York (1798)
  - Cholera in London (1854)
- **Advantages**: Quick observation of disease spread.
- **Limitations**: Privacy issues, difficulty in reflecting population distributions.

Surface Mapping

- **Choropleth Maps**:
  - Example: Filariasis in India, Q fever in the Netherlands.
- **Advantages**: Visualize incidence rates clearly.
- **Limitations**: May hide demographic factors, sensitive to spatial scales.

Figure 2: Example of a choropleth map showing disease incidence.

Advanced Mapping Techniques

Bayesian Smoothing

- Reduces bias in local risk estimation.
- **Example**: Applied in studies of dengue, influenza, and tuberculosis.

Kernel Density Estimation (KDE)

- Identifies dense points and visualizes as smooth surfaces.
- **Example**: Dengue cases in Delhi.

Figure 3: Illustration of Bayesian Smoothing applied to disease data.

Figure 4: KDE showing the density of dengue cases.

Overall Spatial Patterns

Clustering Methods

- **Nearest Neighbour Ratio**:
  - Assesses clustering degree (e.g., rabies in China).
- **Ripley's K Function**:
  - Measures spatial clustering over distance (e.g., leishmaniasis in Brazil).

Figure 5: Visualization of clustering methods.

- Clustering methods help identify hotspots and inform targeted interventions.

Statistical Tests for Clustering

Point Data

- **Nearest Neighbour Ratio**
- **Cuzick and Edwards' test**
- **Ripley's K function**

Aggregate Data

- **Spatial autocorrelation statistics** (e.g., Moran's I)
- These tests are crucial for confirming whether observed patterns are statistically significant.

Hot Spot Detection

Local Indicators of Spatial Association (LISA)

- Identifies clusters of high or low values.

Spatial Scan Statistics

- Detects clusters in space and time (e.g., leishmaniasis in Brazil).

Figure 6: Example of hot spot detection using LISA and spatial scan statistics.

Identifying Risk Factors

Neighbourhood Effect

- Disease risk influenced by nearby cases.

Spatial Heterogeneity

- Variation in disease risk across different areas.

Spatial Regression Methods

- Adjust for neighbourhood effects and spatial heterogeneity.

Figure 7: Illustration of neighbourhood effect and spatial heterogeneity.

Conclusion

- **Spatial epidemiology** provides insights into the spread and control of infectious diseases.
- **Future Directions**: Enhancing GPS methods, optimizing Bayesian estimations.

- **Key Impact**: Improved disease surveillance, hypothesis generation, and strategic control measures.

Figure 8: The impact of spatial epidemiology on disease control.

References

- Lin, C.-H., & Wen, T.-H. (2022). How spatial epidemiology helps understand infectious human disease transmission.