Spatial Statistics

Course Overview

This course provides an in-depth exploration of spatial statistics concepts and case studies, introducing students to the principles and techniques of spatial analysis for examining data using spatially adapted statistical methods. Key topics include point pattern analysis, spatial clustering, spatial autocorrelation, and spatial regression. The course focuses on enhancing students' spatial thinking abilities and equipping them with a strong foundation in statistical methods for spatial data analysis. Designed for students with interests in spatial analysis and geocomputation techniques, this course offers a comprehensive understanding of the essential tools and methodologies required to analyze and interpret spatial patterns and relationships. Students are encouraged to consider using a part of their own research topic as the final project.

Learning Objectives

1. Understand the concept of "spatial" and why "spatial is special".
2. Develop skills to explore and extract valuable spatial information from spatial data.
3. Identify and analyze spatial patterns using appropriate statistical methods.
4. Interpret and communicate spatial relationships using visual and statistical tools.

Topic Covered

1. Introduction (1 week)
    - Spatial statistics
    - Complete spatial randomness
    - Basic components (spatial data, projection, etc.)
2. Point pattern analysis and clustering (2 weeks)
    - Spatial clustering
    - Hotspot detection
    - Spatial scan statistics for cluster detection
3. Spatial autocorrelation (2 weeks)
    - Global pattern, uni-/bi-/multi-variate
    - Local pattern, uni-/bi-/multi-variate
    - Spatial relationships and its effect
4. Spatial regression (3 weeks)
    - Spatial models
    - Geographically Weighted Regression models
    - Multilevel models
5. Framework for spatial modelling (2 week)
    - Common modelling steps and framework
    - Building and evaluating models
6. Applications and emerging trends (2 week)
    - Applications, analysis and interpretations
    - Recent development and potential directions

Reading

- An Introduction to Spatial Data Science with GeoDa:
  https://lanselin.github.io/introbook_vol1/

- Statistical Analysis of Spatial and Spatio-Temporal Point Patterns: https://www-taylorfrancis-com.libproxy1.nus.edu.sg/books/mono/10.1201/b15326/statistical-analysis-spatial-spatio-temporal-point-patterns-peter-diggle

Assessment

Component	Weightage	Description
Lab assignments	40%	Assignments given during the lab session
Final project proposal	20%	Discussion and plan
Final project presentation	30%	Solving a spatial statistics problem
Participation	10%	In-class discussion

Machine Learning and GeoAI for Spatial Problems

Course Overview

Focusing on spatial problems, this course introduces students to the application of machine learning (ML) techniques in analyzing and interpreting spatial data. This course guides students through the entire process of applying ML techniques to address spatial problems. With a strong emphasis on establishing a solid foundation in ML for spatial analysis, students will learn essential concepts, methodologies, and best practices for data preprocessing, model selection, evaluation, and interpretation. Building upon this foundation, the course demonstrates some ML and GeoAI real-world applications. This approach provides students with a comprehensive understanding of the ML pipeline, equipping them with the skills and knowledge to tackle various spatial problems and adapt to emerging challenges in the field. Students are encouraged to consider using a part of their own research topic as the final project.

Learning Objectives

1. Apply ML and GeoAI techniques to analyze spatial data, and confidently navigate the entire ML project pipeline, from data preprocessing and model selection to evaluation and interpretation.
2. Understand the types of ML and GeoAI models, and critically evaluate how these models can effectively solve spatial problems.
3. Interpret and explain the results of ML and GeoAI models applied to spatial data analysis, demonstrating a comprehensive understanding of the ML process and its application to real-world spatial problems.

Topic Covered

1. Introduction to ML and spatial problems (1 week)
   - Overview of ML and its applications in spatial data analysis
   - Types of ML and spatial ML problems
   - The basic procedures of ML
2. Spatial data collection and initial understanding (2 weeks)
   - Spatial data types, structures, and potential issues
   - Exploratory spatial data analysis and visualization
   - Descriptive statistics
   - Spatial relationships and patterns
3. Data preprocessing, feature engineering and feature selection (2 weeks)
   - Missing values/outliers handling and transformation techniques
   - Feature engineering techniques
   - Feature selection techniques
4. Model selection and evaluation Metrics (1 week)
   - Overview of popular machine learning models
   - Model evaluation metrics
   - Understanding the bias-variance trade-off and overfitting
5. Model Training, Validation, and Hyperparameter Tuning (1 week)
   - Data splitting with spatial considerations
   - Model training and validation techniques
   - Hyperparameter tuning methods

6. Model Interpretation, explanation, discussions and limitations (1 week)
    - Model interpretation techniques for spatial data
    - Model visualization and comparison
    - Discussions and limitations
7. Spatial problems, models, applications, and challenges (4 weeks)
    - Unsupervised-based applications
    - Regression-based applications
    - Categorization-based applications
    - GeoAI-based

Reading

- Practical Machine Learning with Python: A Problem-Solver's Guide to Building Real-World Intelligent Systems
  https://link-springer-com.libproxy1.nus.edu.sg/book/10.1007/978-1-4842-3207-1
- Practical Machine Learning for Data Analysis Using Python
  https://www-sciencedirect-com.libproxy1.nus.edu.sg/book/9780128213797/practical-machine-learning-for-data-analysis-using-python
- Handbook of Geospatial Artificial Intelligence:
  https://doi-org.libproxy1.nus.edu.sg/10.1201/9781003308423

Assessment

Component	Weightage	Description
Lab assignments	40%	Assignments given during the lab session
Final project proposal	20%	Discussion and plan
Final project presentation	30%	Solving a spatial problem with ML
Participation	10%	In-class discussion

Scientific Visualization for Spatial Data

Course Overview

This course focuses on scientific visualization techniques for spatial data using Python. Students will learn to create effective visualizations to explore, analyze, and communicate spatial data observations. Topics covered include fundamentals of scientific visualization, statistical data visualization, spatial data visualization, and the technical aspects of visualization integration. Throughout the course, students will gain hands-on experience with Python libraries for visualization.

Learning Objectives

1. Understand scientific visualization principles for spatial data
2. Create effective visualizations using Python libraries
3. Communicate insights through storytelling and infographics

Topic Covered

1. Fundamentals of scientific visualization (2 weeks)
    - The purpose of scientific visualization
    - Figure elements: coordinate systems, typography, colors
    - Figure designs: rule of thumb and basic guidelines
2. Statistical data visualization (3 weeks)
    - Comparing categories
    - Presenting distribution
    - Showing relationships
    - Representing uncertainty and error
3. Spatial data visualization (3 weeks)
    - Basic cartography principles: map projections, map elements, spatial data types
    - Visualizing spatial data: choropleth maps, heatmaps, etc.
    - Spatial patterns analysis and visualization
    - Interactive and web-based mapping
4. Technical aspects of visualization integration (2 weeks)
    - Basic habits for integration
    - Interactive dashboards
    - Static infographics
    - Best practices and things to avoid
5. Storytelling and infographics (2 weeks)
    - Crafting a narrative with data
    - Effective communication and presentation techniques
    - Combining visualizations and text to convey insights
    - Examples of successful data-driven storytelling

Reading

- Scientific Visualization: Python + Matplotlib:
  https://github.com/rougier/scientific-visualization-book/
- Butterick's Practical Typography:
  https://practicaltypography.com/index.html

- Better Data Visualizations:
  https://doi-org.libproxy1.nus.edu.sg/10.7312/schw19310

Assessment

Component	Weightage	Description
Lab assignments	40%	Assignments given during the lab session
Final project proposal	20%	Discussion and plan
Final project presentation	30%	A visualization dashboard or infographic
Participation	10%	In-class discussion