STA465/STA2016/ENV1112
Spatial Data Analysis

Term: Fall 2024
Time: Wednesdays 3-6pm

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Course Description

Spatial data arise in almost every field of study. Examples include environmental measurements, demographics, and tracking the spread of disease incidence. This course is intended as an introduction to analysis techniques for spatial data and aims to provide students with the background necessary to investigate geographically represented data. There are numerous research questions involving spatial data, but in this course, focus will be placed on methods that are relevant in the fields of environment, public health, and social science. Lectures will cover the three main areas of spatial statistics: geostatistical data, lattice (areal) data, and point patterns.

Learning Objectives

The learning objectives of this course are that upon completion, the student should be able to:

- Distinguish different types of spatial data (geostatistical, areal, point process).
- Understand how spatial dependence/autocorrelation plays a role in analysis and modeling.
- Use methods introduced in lectures to investigate spatial patterns in both example datasets provided as exercises and in the class project dataset of your choosing.
- Read and discuss spatial methods in the literature based on an understanding of the basic spatial analytical approaches, principles and main assumptions.

Undergraduate Prerequisite(s): STA302H1/STAC67H3/STA302H5, STA303H1

Course Notes

Lecture notes presented in class will be posted on Quercus.

Readings

Lecture notes and handouts will be the primary source of information for this course. Several textbooks on spatial data analysis will prove to be useful, but lectures will be primarily based on material presented in the following (Note these are NOT REQUIRED):

1) Roger S. Bivand, Edzer J. Pebesma *Spatial Data Science with Applications in R* (2023) https://r-spatial.org/book/
2) Chris Brunsdon and Lex Comber *An Introduction to R for Spatial Analysis & Mapping 2nd edition* (2019), Sage Publishing
3) S. Banerjee, B. Carlin, and A. Gelfand. *Bayesian and Hierarchical Modeling of Spatial Data, 2nd edition* (2014), Chapman and Hall. (Advanced)

Technological Proficiency and Hardware/Software Required

Computation using R (downloaded from http://cran.r-project.org) and reports in RMarkdown (https://rmarkdown.rstudio.com/) will be used throughout the semester. Students without computing experience may be allowed to take the course but should be aware that they will need to become familiar with R coding on their own.

There will not be a separate computer lab, but some lecture time will be set aside to go through code and procedures to familiarize students with the implementation of various spatial methods. Students should bring their laptop to class and if R and RStudio are not installed, students may use JupyterHub https://live-datatools.pantheonsite.io/

Description and Assessment of Assignments

Assignments: There will be 5 assignments given throughout the semester (approximately bi-weekly). Students may discuss the problems with one another; however, individual solutions must be submitted, and copying will not be tolerated. Late assignments will be penalized by 10% per day past the due date (except when there is a verifiable illness).

Assignments for ENV and STA students will differ slightly (more statistics focused questions for the STA students and applied questions for ENV students).

Project Plan (Mid-term): The project consists of statistical analysis of a real spatial dataset. In preparation for the final project, you will submit a brief mid-semester report that describes the dataset you have chosen. Preliminary data summaries should be submitted along with an analytic plan (i.e. what spatial methods you will use).

Final Project: The final project is a formal analysis of a spatial dataset that is written up like a scientific paper (Introduction, Methods, Results, Discussion). It should include tables and figures summarizing your data and modeling results. Work must be done individually and originality will be assessed. A short recorded presentation will be submitted as well.

In-Class Discussion: The instructor will occasionally post readings that will be discussed at the beginning of the class. Participation is required.

Grading Breakdown

Assignment	**% of Grade**
Homework (5)	50%
In-Class Discussion	5%
Project Plan (Midterm)	5%
Final Project	40%

Weekly Breakdown

	Topics/Daily Activities	**Deliverable/ Due Dates**
Week 1 September 4	Overview of different types of spatial data, introduction to R tools needed for spatial analysis, review of non-spatial regression	
Week 2 September 11	Data visualization, mapping, geocoding	**HW0**
Week 3 September 18	Geostatistics: variograms and covariance functions	
Week 4 September 25	Geostatistics: fitting variogram functions	**HW 1 Due**
Week 5 October 2	Geostatistics: kriging	
Week 6 October 9	Areal data: neighborhoods, testing for spatial association	**HW2 Due**
Week 7 October 16	Areal data: global and local tests of association	
Week 8 October 23	Areal data: CAR and SAR models, inference	**HW3 Due**
Week 9 October 30	Fall Break – no class	
Week 10 November 6	Point process data: types of spatial patterns, spatial randomness	**Project Plan (midterm)**
Week 11 November 13	Point process data: spatial clustering and testing for clustering	**HW4 Due**
Week 12 November 20	Spatial data computation, common machine learning	
Week 13 November 27	Special topics: Spatio-temporal modeling, Bayesian disease mapping	**HW5 Due**
Finals Period December 13	Final Project Due (no class)	**Final Paper, Short Recorded Presentation**

Statements on Academic Conduct and Support Systems

Academic Conduct

All suspected cases of academic dishonesty will be investigated following procedures outlined in the *Code of Behavior on Academic Matters*. If you have questions or concerns about what constitutes appropriate academic behavior or appropriate research and citation methods, please reach out to me. Note that you are expected to seek out additional information on academic integrity from me or from other institutional resources (for example, the University of Toronto website on Academic Integrity).

Accommodations

The University provides academic accommodations for students with disabilities in accordance with the terms of the Ontario Human Rights Code. This occurs through a collaborative process that acknowledges a collective obligation to develop an accessible learning environment that both meets the needs of students and preserves the essential academic requirements of the University's courses and programs.

Students with diverse learning styles and needs are welcome in this course. If you have a disability that may require accommodations, please feel free to approach me and/or the Accessibility Services* office. Accessibility Services on the St. George campus

Religious Observances

The University provides reasonable accommodation of the needs of students who observe religious holy days other than those already accommodated by ordinary scheduling and statutory holidays. Students have a responsibility to alert members of the teaching staff in a timely fashion to upcoming religious observances and anticipated absences and instructors will make every reasonable effort to avoid scheduling tests, examinations or other compulsory activities at these times. Please reach out to me as early as possible to communicate any anticipated absences related to religious observances, and to discuss any possible related implications for course work.

Family Care Responsibilities

The University of Toronto strives to provide a family-friendly environment. You may wish to inform me if you are a student with family responsibilities. If you are a student parent or have family responsibilities, you also may wish to visit the Family Care Office website at familycare.utoronto.ca.

Intellectual Property Statement

Course material that has been created by your instructor (i.e. lecture slides, term test questions/solutions and any other course material and resources made available to you on Quercus) is the intellectual property of your instructors and is made available to you for your personal use in this course. Sharing, posting, selling or using this material outside of your personal use in this course is not permitted under any circumstances and is considered an infringement of intellectual property rights.

Land Acknowledgement

A land acknowledgement is a way of honoring the Indigenous people who have lived and worked here for thousands of years, and whose land was colonized. It is also an invitation to reflect on the history of this land and we encourage you to consider the history of the land wherever you are now. https://native-land.ca/