Spatial Statistics and Hierarchical Modeling for Dependent Data

STA6709 Section SPAT, 3 credit hours
Class Periods: TR periods 9-10 (4:05-6:00 PM)
Location: 426 McCarty Hall C
Academic Term: Spring 2023

Instructor:
Dr. Nikolay Bliznyuk
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Office Hours: 406 McCarty Hall C, times TBA

Teaching Assistant/Peer Mentor/Supervised Teaching Student: No TA

Course Description
This is a course on analytical and computational methods of spatial statistics for modeling, inference and prediction for dependent data, including point-referenced (geostatistical), areal and point process data. The methods (including uncertainty quantification using hierarchical Bayesian models) generalize to Gaussian process and GMRF models popular in machine learning and other areas of engineering. The course is targeted at graduate students in data sciences, engineering and quantitative life sciences.
Topics include models for point-referenced/geostatistical, areal and spatial point process patterns data, spatial regression, hierarchical Bayesian framework for spatial (generalized) linear models; advanced topics: spatio-temporal processes, multivariate random fields, approximate Bayesian inference using INLA.

Course Pre-Requisites / Co-Requisites
Prerequisites: mathematical statistics emphasizing inference (e.g., PHC6092 or STA6327) and regression (e.g., STA6207). Knowledge of scientific/statistical computing (e.g., in R, Python or Matlab) and undergraduate mathematics (multivariate calculus and linear algebra) appropriate for a graduate student in data sciences will also be assumed. A pretest will be given on the first day of classes to determine if a student has the prerequisites met.

Course Objectives
- Learn the language of and the principles behind spatial data analysis - modeling, inference and prediction
- Describe the three main areas of spatial statistics: models for geostatistical, areal, and point process data;
- Read and discuss new spatial statistics methods in the literature based on an understanding of the basic spatial statistics approaches, principles and main assumptions.
- Learn and be able to use R to implement and apply models to analyze for different types of spatial data.
- Establish command of methods through homework and a final project
- Reinforce the use of R as a statistical computing language for data science – for statistical inference, prediction, scientific computing and data visualization

Materials and Supply Fees
None

Required Textbooks and Software
- *Hierarchical Modeling and Analysis for Spatial Data*
- Banerjee, Carlin and Gelfand
- 2014, 2nd edition; CRC press
- ISBN 1439819173
- No need to purchase the text, as necessary materials will be provided in class

R and Python languages and appropriate computing environments (e.g., R Studio and Anaconda) are freely available

Recommended Textbooks
N/A

Course Schedule

week	topic
1	Overview Of Spatial Data Problems
	CORE TOPICS
2,3	Gaussian Processes (GPs): Prediction, Interpolation And Smoothing
4,5	Point-Referenced (Geostatistical) Data Models
6,7	Areal Data Models
7,8	Models for Point Patterns
9	Essentials Of Bayesian Inference
10,11	Hierarchical Modeling For Univariate Spatial Data
	SPECIAL TOPICS
12	Nongeostatistical Approaches To Interpolation And Smoothing
13	Multivariate Spatial Modeling
14	Spatiotemporal Modeling
15	Approximate Bayesian Inference Using Integrated Nested Laplace Approximation (INLA)
	Project Presentations

Depending on the student backgrounds and interests, some of the special topics above may vary by year.
A more detailed version of this schedule is in the Supplements at the end this syllabus.

Attendance Policy, Class Expectations, and Make-Up Policy
Attendance at all times is expected. Excused absences must be in compliance with university policies in the Graduate Catalog (http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#attendance) and require appropriate documentation. Make-ups are not allowed except for documented health, family emergency or work reasons.

Evaluation of Grades

Assignment	Total Points	Percentage of Final Grade
Homework Sets (approx. 4-5)	100 each	50%
Project	100	50%
		100%

Homework will be assigned regularly (approximately, biweekly). Project (requiring about 40 hours to complete) will consist of a proposal (10 pts), report (60 pts) and presentation (30 pts). Project details are provided in the Supplements at the end of the syllabus.

Grading Policy
Tentatively, the following grading scale will be adopted; grades may be curved to the advantage of students.

Percent	Grade	Grade Points
93.4 - 100	A	4.00
90.0 - 93.3	A-	3.67
86.7 - 89.9	B+	3.33
83.4 - 86.6	B	3.00
80.0 - 83.3	B-	2.67
76.7 - 79.9	C+	2.33
73.4 - 76.6	C	2.00
70.0 - 73.3	C-	1.67
66.7 - 69.9	D+	1.33
63.4 - 66.6	D	1.00
60.0 - 63.3	D-	0.67

0 - 59.9	E	0.00

More information on UF grading policy may be found at:
http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades

Students Requiring Accommodations
Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting https://disability.ufl.edu/students/get-started/. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Course Evaluation
Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/.

In-Class Recording
Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A "class lecture" is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To "publish" means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

University Honesty Policy
UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:
- Your academic advisor or Graduate Program Coordinator
- Robin Bielling, Director of Human Resources, 352-392-0903, rbielling@eng.ufl.edu
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use
All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy
There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: https://registrar.ufl.edu/ferpa.html

Campus Resources:
Health and Wellness

U Matter, We Care:
Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: http://www.counseling.ufl.edu/cwc, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence
If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)
Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.

Academic Resources

E-learning technical suppor*t*, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling. https://www.crc.ufl.edu/.

Library Support, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

Student Complaints Campus*:* https://care.dso.ufl.edu.

On-Line Students Complaints*:* http://www.distance.ufl.edu/student-complaint-process.

SUPPLEMENTS: Project description

The project will emphasize creative application of the methods/knowledge developed in the course. Ideally, the application would be to your line of research and data (your own or of your immediate collaborators - advisor or fellow students). If you do not have suitable data, please check out the sources at the end of this description for the publicly available datasets. Otherwise, a good project could be a replication and extension of the results of a methodological paper of interest (select papers will be provided, or you may propose your own). "Creative application" does not allow merely running someone else's code without making other contributions. **Plagiarism is totally inappropriate and prohibited (just do not do it); it will result in a failing grade for the course. Course staff will run all project reports through UF Ithenticate. All work should be done individually (unless explicitly permitted by the instructor – for more ambitious projects).** *Projects already completed for other classes/causes are not acceptable. Example 1 - unacceptable: in a previous semester, a student wrote a paper for a journal or did a project for a different class, and now wants to submit it without major changes or additional relevant work as the class project. Example 2 – acceptable: in a previous semester, a student wrote a paper for a journal or did a project for a different class, but wants to do a major extension of the work using the techniques learned in this class. This would make a potentially very good project, but the student needs to be explicit about what is new and what not. Only the new work will constitute the course project in this case.* The project will be used to assess the knowledge and skills that students acquired in the course; for that reason, the work must be done individually and without assistance from the course staff.

Deliverables: a one-page proposal, a short technical report as described below, and a 12-15 minute presentation followed by 3-5 minutes of questions.

Deadlines: (very tentative; will be revised appropriately each year)

Mid-to-late March, date TBA: submit your proposal by email to nbliznyuk@ufl.edu so that we can visit individually shortly after that (individual slots TBA after your proposals have been received).

Mid-April: in-class presentations; format TBA depending on the class size (at least 12 minutes per presenter)

End of April: final report (in pdf format, accompanying code and the actual data that you used, if using a publicly available source; put all in a folder named after you and create a zip or rar archive; test archive before submitting), submit using Dropbox file request (same link as above): tinyurl.com/nbliznyuk-submit-files

Expectations for the proposal (1 page):

The main goal behind the proposals is to ensure that the projects are neither too simple nor too ambitious (i.e., will require about 40 hours to complete – loosely, an equivalent of 4-5 weeks of homework effort, where writing will play a significant role), there is no duplication among students and that you have the necessary relatively clean data to analyze. Please specifically discuss what you propose to do (e.g., "big picture" and specific methods), why you focus on this particular problem (significance, motivation and relevance to the course) and available data (specifically, what are primary response variable(s) and features, what are n and p, etc). Your project should be "shovel ready", i.e., a bit of data preprocessing may be necessary but you should not be spending more than 20% (ideally, 10%) of your total time budget on cleaning and data manipulation. The typesetting format of the proposal should be the same as for the project (please read below).

Expectations for the report (8 pages):

Report should be organized as a short paper appropriate to your field; e.g., a short abstract (100 words), intro (including motivation), background and data, methods, analysis/results, conclusions/discussion. *Any software/languages/environments may be used for the project (i.e., not necessarily R).* The length is about 8 pages (not counting references, appendices or supplements) double-spaced, using 12 pt font: roughly 6 pages of text and 2 pages for your most essential tables and figures; **single-column only**. If necessary, the paper may have an Appendix with additional figures and tables. Data, code and other supplemental information should be made available as part of "Supplementary Materials" unless the data are confidential (please discuss "deliverables" in the proposal). Please check out the project evaluation rubric in a separate file.

SUPPLEMENTS: Detailed Syllabus

week	topics
1	**Overview Of Spatial Data Problems**
	Introduction To Spatial Data And Models
	Fundamentals Of Cartography
2,3	**Gaussian Processes (GPs): Prediction, Interpolation And Smoothing**
	GPs As An Extension Of Multivariate Normal Distribution
	Best Linear Unbiased Prediction Under a GP Model
	Computation
4,5	**Basics Of Point-Referenced (Geostatistical) Data Models**
	Elements Of Point-Referenced Modeling
	Spatial Process Models
	Exploratory Approaches For Point-Referenced Data
	Classical Spatial Prediction
6,7	**Basics Of Areal Data Models**
	Exploratory Approaches For Areal Data
	Brook's Lemma And Markov Random Fields
	Conditionally Autoregressive (CAR) Models
	Simultaneous Autoregressive (SAR) Models
7,8	**Models for Point Patterns**
	Homogeneous and Inhomogeneous Poisson Point Processes
	Related Models
9	**Basics Of Bayesian Inference**
	Introduction to Hierarchical Modeling And Bayes Theorem
	Bayesian Inference
	Bayesian Computation
10,11	**Hierarchical Modeling For Univariate Spatial Data**
	Stationary Spatial Process Models
	Generalized Linear Spatial Process Modeling
	Nonstationary Spatial Process Models
	Areal Data Models
	General Linear Areal Data Modeling
12	**Nongeostatistical Approaches To Interpolation And Smoothing**
	Generalized Additive Models (GAMs)
	Nonstatistical Approaches
13	**Multivariate Spatial Modeling**
	Separable Models
	Coregionalization Models
	Other Constructive Approaches
	Multivariate Models For Areal Data
14	**Spatiotemporal Modeling**
	General Modeling Formulation
	Point-Level Modeling With Continuous Time
	Nonseparable Spatio-Temporal Models
	Dynamic Spatio-Temporal Models
15	**Approximate Bayesian Inference Using Integrated Nested Laplace Approximation (INLA)**