

BIOS 791: Empirical Processes and Semiparametric Inference

Fall 2024 (3 Credit Hours)

Instructor: Professor Michael R. Kosorok, 3105 I McGavran-Greenberg (MCG),
Email: kosorok@unc.edu

Grader: Yating Zou, Email: yating@live.unc.edu

Time and location: Mondays and Wednesdays, 9:05-10:20AM, room .

Faculty office hours: Mondays 3:00-5:00PM, 3105 I MCG.

Grader office hours: Thursdays 2:00-3:00PM, room 1303 MCG.

Final exam: Final project, but no final exam.

Prerequisites: BIOS 760 or equivalent.

Required texts:

- Kosorok (2008), *Introduction to Empirical Processes and Semiparametric Inference*, Springer-New York.
- Kosorok (2024+), 2nd Edition Draft, Chapters 6-9.

Supplemental texts:

BKRW: Bickel, Klaassen, Ritov and Wellner (1993), *Efficient and Adaptive Estimation for Semiparametric Models*, Springer.

V: van der Vaart (1998), *Asymptotic Statistics*, Cambridge University Press.

VW: van der Vaart and Wellner (2023), *Weak Convergence and Empirical Processes: With Applications to Statistics*, Second Edition, Springer.

Summary: Although theory of statistical inference has achieved a certain maturity in many fields of investigation, increasingly complex statistical and machine learning models are emerging in clinical research, the social sciences, genetics, economics, atmospheric sciences, and in many other areas. Empirical process theory has proven to be a powerful tool for working with these complex models. For example, semiparametric models, such as the Cox proportional hazards model or generalized additive models, consist of both a parametric and a nonparametric (infinite dimensional) component. These models are flexible and appealing because very few assumptions are made on the nonparametric part. However, this increased flexibility makes distribution theory quite challenging and modern empirical process techniques are usually required. This is currently an extremely active as well as demanding area of statistical research.

In addition to examining numerous examples, the course will develop in each student the technical skills to enable application of empirical process and semiparametric methods in statistics. Other areas to be covered include stochastic convergence in metric spaces, Brownian motion and Brownian bridges, Gaussian processes, Glivenko-Cantelli and Donsker theorems, entropy calculations, bootstrapped empirical processes; the functional delta method, Z-estimators, M-estimators, rates of convergence, semiparametric efficiency, semiparametric estimating equations, and nonparametric maximum likelihood estimation.

Course requirements: The grade for the course will depend on regular homework assignments. 25 homework problems (in 11 problem sets) will be assigned throughout the semester to facilitate learning the material (worth 2 points per problem). There will also be three miniprojects that involve (1) finding a recent article on a related topic and describing what the researchers have done (10 points possible), (2) verifying some of the results (20 points possible), and (3) identifying interesting areas for future research (20 points possible). The homework assignments and miniproject descriptions are given below. The final miniproject (MP3) must be turned in by 9:00AM on Wednesday, December 4, 2024. Grades will be determined on the basis of the number of points achieved (out of 100 possible): H (90–100%), P (80–90%), L (70–80%), and F (less than 70%). There will be no in-class exams.

Schedule of topics, chapters, and due dates. The assignments are due on Wednesday at the beginning of class for the given week. “PS” stands for problem set and “MP” stands for miniproject.

Week	Dates	Topic	Chapters	Due
1	Aug. 19, 21	introduction and overview	1–4	
2	26, 28	metric spaces, etc.	5–6	PS1
3	Sep. 4	”		PS2
4	9, 11	stochastic convergence	7	PS3, choice
5	16, 18	empirical process methods	8	PS4
6	25	entropy calculations	9	PS5
7	30, Oct. 2	empirical process bootstrap	10	PS6
8	7, 9	the functional delta method	12	MP1
9	14, 16	Z-estimators	13	PS7
10	21, 23	M-estimators, etc.	14–15	PS8
11	28, 30	”		MP2
12	Nov. 4, 6	Hilbert spaces, etc.	16–17	PS9
14	11, 13	semiparametric inference	18	PS10
15	18, 20	”	19-20	PS11
16	25	”		
17	Dec. 2 4	”		MP3

Miniprojects:

- MP1: For this project, choose a recent statistical article (published since 2015) which utilizes empirical process methods and/or semiparametric inference. The major statistical or probability journals should be used. Please try to find a paper that involves a topic which seems to have significant future research potential, write a 2–3 page summary of the paper (you do not have to verify any math), paying particular attention to the practical issues being addressed. The choice of paper paper(s) need to be approved on or before September 11, 2024. The total points possible are 10.
- MP2: For this project, choose a recent statistical article (published since 2015) which utilizes empirical process methods and/or semiparametric inference. You may use the same paper you used for MP1. Please try to make sure that the paper contains significant mathematical-statistical content and involves a topic which seems to have significant future research potential. Identify 1–3 key steps in the proofs of the results which require empirical process and/or semiparametric techniques and then verify those steps (I want you to show me that you understand the steps involved). Write a 2–3 page summary of your verification of these steps along with any other insight into the workings of the technical aspects of the paper which you think are

interesting. One question to ask is whether the author(s) could have shown the same results using simpler methods. You may want to get an early start on this paper and meet with me several times to make sure you are comfortable with the main technical aspects of the selected paper (I am quite happy to check your work and give clues if needed). The total points possible for MP2 are 20.

MP3: For this project, choose a recent statistical article (published since 2015) which utilizes empirical process methods and/or semiparametric inference. You may use the same paper(s) used for projects 1 and 2. Make sure that the chosen paper can provide some information about potential research projects. Identify 1–3 promising problems and/or research questions which could be of interest to the statistical community and which involve empirical process methods and/or semiparametric inference. Write a 2–3 page summary of your findings and include an evaluation of the potential impact if the proposed research were successful. The total points possible are 20. You may want to get an early start on this paper and meet with me several times to make sure you are headed in the right direction.

Problem Sets: Non-asterisked problem numbers are taken from Kosorok (2008), Asterisked problem numbers are taken from Kosorok (2024+):

Assignment	Exercises
PS1	2.4.1, 3.5.1
PS2	4.6.1, 4.6.8
PS3	6.5.8*, 6.5.14*
PS4	7.5.5*, 7.5.7*
PS5	8.5.1*, 8.5.7*
PS6	9.6.6*, 9.6.10*
PS7	10.5.1, 12.3.2
PS8	13.4.2, 14.6.9, 14.6.10
PS9	15.6.2, 17.4.4, 17.4.5
PS10	18.5.3, 18.5.4
PS11	19.5.3, 19.5.7, 20.3.4

Reference texts: The following additional reference texts may be useful from time to time:

1. Andersen, Borgan, Gill, and Keiding (1993). *Stochastic Models Based on Counting Processes*.
2. Bickel, Klaassen, Ritov, and Wellner (1993). *Efficient and Adaptive Estimation for Semiparametric Models*. (abbreviated BKRW)
3. Ethier and Kurtz (1986). *Markov Processes: Characterization and Convergence*.
4. Fleming and Harrington (1991). *Counting Processes and Survival Analysis*.
5. van de Geer (1999). *Empirical Processes in M-Estimation*.
6. Pollard (1984). *Convergence of Stochastic Processes*.
7. Pollard (1990). *Empirical Processes: Theory and Applications*.
8. Shorack and Wellner (1986). *Empirical Processes with Applications to Statistics*.

Additional Expectations, Policies and Resources:

Accessibility at UNC Chapel Hill. The University of North Carolina at Chapel Hill facilitates the implementation of reasonable accommodations, including resources and services, for students with disabilities, chronic medical conditions, a temporary disability or pregnancy complications resulting in barriers to fully accessing University courses, programs and activities. Accommodations are determined through the Office of Accessibility Resources and Service (ARS) for individuals with documented qualifying disabilities in accordance with applicable state and federal laws. See <https://ars.unc.edu/>; phone 919-962-8300; email ars@unc.edu.

Attendance/Participation. Your attendance and active participation are an integral part of your learning experience in this course. If you are unavoidably absent, please notify the course instructor. No right or privilege exists that permits a student to be absent from any class meetings, except for these University Approved Absences:

1. Authorized University activities
2. Disability/religious observance/pregnancy, as required by law and approved by Accessibility Resources and Service (<https://ars.unc.edu/>) and/or the Equal Opportunity and Compliance Office (<https://eoc.unc.edu/what-we-do/accommodations/>).
3. Significant health condition and/or personal/family emergency as approved by the Office of the Dean of Students (<https://dos.unc.edu/>), Gender Violence Service Coordinators (<https://gvsc.unc.edu/>), and/or the Equal Opportunity and Compliance Office (<https://eoc.unc.edu/what-we-do/accommodations/>).

Use of Generative AI (Gen AI). No AI use in this class is allowed for any homework or exams. Generative artificial intelligence (AI) tools (e.g., ChatGPT) that generate text, images, and media, could aid brainstorming, research, and content creation, and may be useful in public health practice. However, these tools must be used ethically, transparently, and with the understanding of their limitations including circumstances when AI use hinders rather than promotes learning.

Counseling and Psychological Services at UNC Chapel Hill. CAPS is strongly committed to addressing the mental health needs of a diverse student body through timely access to consultation and connection to clinically appropriate services, whether for short or long-term needs. Go to their website: <https://caps.unc.edu>, call them at 919-966-3658, or visit their facilities on the third floor of the Campus Health Services building for a walk-in evaluation to learn more. Note: All counseling services provided are completely confidential and are in no way connected to your academic record.

Honor Code. To ensure effective functioning of the Honor System at UNC (see <http://studentconduct.unc.edu/honor-system>), students are expected to:

- Conduct all academic work within the letter and spirit of the Honor Code, which prohibits the giving or receiving of unauthorized aid in all academic processes.
- Learn the recognized techniques of proper attribution of sources used in written work; and to identify allowable resource materials or aids to be used during completion of any graded work.
- You are welcome and encouraged to discuss course materials and work on homework in groups to help each other understand the concepts better, but all assignments need to be written and completed individually on your own and with your own words. Plagiarism is not allowed in this course.

If you have any questions about your rights and responsibilities, consult the Office of Student Conduct (<https://studentconduct.unc.edu/>) or review the following resources: Honor System (<https://studentconduct.unc.edu/honor-system/>); Honor System module (<https://studentconduct.unc.edu/honor-system-module/>); UNC Library’s plagiarism tutorial (<https://guides.lib.unc.edu/plagiarism/>); UNC Writing Center’s handout on plagiarism (<https://writingcenter.unc.edu/tips-and-tools/plagiarism/>).

Inclusive Excellence. We are committed to expanding diversity and inclusiveness across the School — among faculty, staff, students, on advisory groups, and in our curricula, leadership, policies and practices. We measure diversity and inclusion not only in numbers, but also by the extent to which students, alumni, faculty, and staff members perceive the School’s environment as welcoming, valuing all individuals, and supporting their development.

For more information about how we are practicing inclusive excellence at the Gillings School, visit the following webpages: Inclusive Excellence (<https://sph.unc.edu/resource-pages/inclusive-excellence/>), Inclusive Excellence Action Plan (<https://sph.unc.edu/diversity/i-e-action-plan/>), Minority Health Conference (<https://minorityhealth.web.unc.edu/>), and National Health Equity Research Webcast (<https://sph.unc.edu/mhp/nat-health-equity-research-webcast/>).

Additional campus resources include: the LGBTQ Center (<https://lgbtq.unc.edu/>); Non-Discrimination Policies at UNC Chapel Hill (<https://eoc.unc.edu/our-policies/policy-statement-on-non-discrimination/>); Ombuds (<https://ombuds.unc.edu/>); and Prohibited Discrimination, Harassment, and Related Misconduct at UNC Chapel Hill (<https://eoc.unc.edu/our-policies/ppdhrm/>).

In this class, we practice the Gillings School’s commitment to inclusion, diversity, and equity. Some of the ways we do this are as follows:

- Treat all members of the Gillings and UNC community (students, faculty, and staff) as human persons of equal worth who deserve dignity and respect, even in moments of conflict and disagreement.
- Contribute to creating a welcoming and inclusive classroom environment, where all are able to learn and grow from one another.
- Acknowledge and respect the diversity of experiences that others bring to the classroom and the ways in which this richness enhances everyone’s learning.

Land Acknowledgment. Please read The Gillings School’s Land Acknowledgment (<https://sph.unc.edu/diversity/land-acknowledgement/>).

Student Feedback and Equity Concerns. The Gillings School has in place a mechanism for students to provide feedback (<https://feedback.sph.unc.edu/>), including specifically equity concerns and bias-related issues. You can use this form to describe feedback, both positive and negative, about anything including issues related to your experience as a student at Gillings, administrative processes, and classroom activities. This form will also allow you to specifically describe incidents in which racial or other equity-related bias, or microaggressions, occurred. You may submit this form anonymously. However, for us to follow up and provide the necessary support, we encourage you to include your contact information. For further information, please visit the Student Feedback and Equity Concerns FAQ (<https://sph.unc.edu/students/student-feedback-and-equity-concerns-faq/>).

Please note that this form does not take the place of any University process or policy. If you would like to report an incident under the University's policy on Prohibited Discrimination, Harassment, and Related Misconduct including Sexual and Gender Based Harassment, Sexual Violence, Interpersonal Violence, and Stalking (<https://policies.unc.edu/TDClient/2833/Portal/KB/ArticleDet?ID=132487#autoid-drq2r>), please visit Safe At UNC (<https://safe.unc.edu/>) or the Equal Opportunity and Compliance Office (EOC: <https://eoc.unc.edu/>) for additional information, including resources, contact, and reporting options.

Technical Support. Your instructor in general cannot resolve technical issues, but it's important to notify them if you are experiencing issues. If you have problems submitting an assignment or taking a quiz in canvas, immediately do the following:

1. Contact the UNC Information Technology Services (ITS) department with the time you attempted to do your course action and what the course action was.
2. Email your instructor with the information you sent to ITS and what time you sent the information. The ITS department provides technical support 24-hours per day, seven days per week. If you need computer help, please contact the ITS Help Desk by phone at +1-919-962-HELP (4357), or by online help request (<https://sso.unc.edu/idp/profile/SAML2/Redirect/SSO?execution=e2s1>), or by UNC Live Chat (<https://sso.unc.edu/idp/profile/SAML2/Redirect/SSO?execution=e3s1>).

Safety and Emergency Information at Gillings. Though unlikely, there is always a possibility that there might be some type of emergency during the semester. Emergencies come in many different forms — weather, medical, fire and ones involving people intending to do harm. As you probably know from your own experience, pre-K through 12th-grade students prepare in advance for emergency situations. As college students, you too need to think in advance about emergency situations. I would like to take a few moments to talk about actions to take in the event of an emergency in our classroom setting:

If there is an emergency, I will stop teaching right away.

- When it is safe to do so, we will call 9-1-1 and identify our building and room number, as well as the issue.
- There are some areas on campus, such as indoors, where you can't hear the Alert Carolina siren. The first warning of an emergency may come to our attention via a messenger at the classroom door or through a personal electronic device.
- If you see or experience something unusual or concerning — before, during or after class — that may lead to an emergency, please let me or another faculty member/administrator or Gillings School security know as soon as possible. Alert me even if you have only an inkling that something may not be right. It is very important that you make me aware. In a weather emergency, you may not be able to hear the emergency siren if you are inside of a building. If you are inside, move to an interior room on the lowest floor, and stay away from windows. In a medical/mental health emergency, please make space for first responders to do their work. UNC Police, Fire Department and EMS respond to all medical calls on campus. In the case of fire, do not attempt to carry anything in your hands. Exit quickly in as orderly a way as possible. Help others as much as possible. In a situation in which one or more people intend

to do harm, assess the situation and make a decision. Unfortunately, there may not be a clear “right” answer. However, your circumstances may make one of these actions the only viable option to protect yourself.

- Run: Have an escape route and plan in mind, leave your belongings behind, keep your hands visible, exit the building as quickly and safely as possible, distancing yourself from the threat, and follow law enforcement’s direction.
- Hide: If you cannot safely evacuate your building or are unsure of the location of the threat, secure your room, classroom or office, creating as many barriers between you and the threat. If you are caught outside, seek shelter inside the nearest building, and secure an interior space. Take the following actions: Lock or secure doors, turn off lights, move into concealed areas of the room away from doors and windows, silence your mobile devices and remain calm and quiet.
- Fight: Use this as a last resort if your life is in imminent danger. If there are no other options to safely escape and you are confronted by the intruder, attempt to disrupt or incapacitate the intruder using all available resources (e.g., acting aggressively, yelling, throwing items, improvising weapons). If you need to exit the building in an emergency, seek cover behind buildings, cars and other solid structures — go as far away as possible while still staying safe. Keep going until you know that you are out of danger. Here is what you need to do next: Take the time you need to identify the different entrances and exits in this room and this building. There are many ways in and out of this building. The next time you come to class, think about possible routes. Try different routes so you are aware. Be better prepared for UNC-specific safety procedures by visiting Carolina Ready.
- Important Contacts:
 - Emergencies, anywhere: Call 911
 - Gillings School Resources:
 - Gillings DPS Security: (919) 357-8037
 - Building Issues: (919) 843-7872
 - Gillings Student Affairs: (919) 966-2499

Title IX Resources at UNC Chapel Hill. Any student who is impacted by discrimination, harassment, interpersonal (relationship) violence, sexual violence, sexual exploitation, or stalking is encouraged to seek resources on campus or in the community. Please contact the Director of Title IX Compliance (Adrienne Allison – Adrienne.allison@unc.edu), Report and Response Coordinators in the Equal Opportunity and Compliance Office (reportandresponse@unc.edu), Counseling and Psychological Services (confidential), or the Gender Violence Services Coordinators (gvsc@unc.edu; confidential) to discuss your specific needs. Additional resources are available at safe.unc.edu.

Syllabus Changes. The instructor reserves the right to make changes to the syllabus, including topics, readings, assignments, and due dates. Any changes will be announced as early as possible.