PURDUE
UNIVERSITY

ECE 695 Probabilistic Causal Inference

Syllabus

Fall 2021

Course Information

ECE 695 Probabilistic Causal Inference
CRN: 26721
Meeting time: Tuesdays and Thursdays at 10:30 am - 11:45 am
Location: Hampton Hall of Civil Engineering 2113
Course credit hours: 3
Course web page: https://www.muratkocaoglu.com/ece695
Piazza: http://piazza.com/purdue/fall2021/ece69500230

The information in this syllabus is subject to change as needed in response to unexpected developments, although the instructor will attempt to avoid disruptions as much as possible.

Information about the Instructor(s)

Prof. Murat Kocaoglu
Office: MSEE 362
Email: mkocaoglu@purdue.edu

Lectures

Lectures will be delivered in-person on the black board.

Office Hours

Prof. Murat Kocaoglu Friday 9:30-10:30am at MSEE 362

Piazza

Please sign up and use the following Piazza forum. Please participate the discussions on Piazza not only by asking questions but also answering them. You can find the access code on Brightspace.
http://piazza.com/purdue/fall2021/ece69500230

Course Description

Causality is a fundamental concept, which plays critical role in several areas today including machine learning and data science. In this course, we are going to learn the tools for modeling probabilistic causality. We will learn causal graphs, and how they can be used for estimating interventional queries. We will also cover learning causal graphs from observational as well as interventional data. Finally, we are going to briefly discuss the notion of counterfactuals. The course also has a research component and students are expected to develop or outline a novel algorithmic idea/solution or a new application of the tools they learn in the class to their research, which they will describe in their project presentation and project report.

Learning Outcomes

A student who successfully fulfills the course requirements will have demonstrated an ability to identify causal questions, understand the range of assumptions and the corresponding algorithms needed to answer these questions. Furthermore, they will have demonstrated potential to either conduct research on causal inference or apply the tools they learned throughout the course in their research.

Texts

- Required Textbook:
  - No required textbooks
- Supplementary Material:
  - Pearl, J. (2009). *Causality*. Cambridge university press.
  - Pearl, J. (2014). *Probabilistic reasoning in intelligent systems: networks of plausible inference*. Elsevier.
  - Koller, D., & Friedman, N. (2009). *Probabilistic graphical models: principles and techniques*. MIT press.
  - Spirtes, P., Glymour, C. N., Scheines, R., & Heckerman, D. (2000). *Causation, prediction, and search*. MIT press.

Assignments and Points

This is a research-oriented course. Therefore, most of the grade will be based on a research presentation and a research report to be submitted at the end of the semester. Preferred group size for projects is 1, i.e., students are expected to work on the project on their own with guidance from the instructor. Students are encouraged to start the project as early as possible in the semester and frequently consult with the instructor in office hours or on Piazza. There is also one midterm and one paper presentation, each worth 25 percent of your grade.

Midterm 1: 25%

Date : 9/21 Tuesday, in-lecture.
Format : Basics of d-separation, do calculus and identifiability on causal graphs.

Paper presentation: 25%

Date : Project presentations start 11/2 (tentative). Exact date for each student will be determined later in the semester based on the enrollment.
Format : Presentation of a research paper. Instructor will provide a pool of papers to choose from. Other papers are acceptable with the instructor's approval. After an in-depth coverage of the technical details of the paper, the students are expected to criticize it and brainstorm extension ideas.

Research project presentation: 25%

Date : Project presentations start 11/23 (tentative). Exact presentation date for each student will be determined later in the semester based on the enrollment.
Format : A 30-minute presentation outlining the research contribution to be submitted as a project report. This will be an important feedback from the instructor and the other students which should be taken into account in the project report. Please start the project as early as possible in the semester and discuss with the instructor throughout the semester to get OK for the scope in office hours, via email or over Piazza.

Research project report: 25%

Date : 12/15
Format : A 4-page pdf – excluding appendix and references – to be submitted to the instructor via email with the subject line *ECE695 Project Report*. The paper should contain novelty either as a new algorithmic solution to a problem within the scope of the course or a novel promising research direction with the detailed outline of the approach.

Grading Scale

100 : A+
85–99 : A
75–85 : B
60–75 : C
50–60 : D
0–50 : F

This is a new class, and the instructor reserves the right to be more generous with grades later in the semester.

Incomplete Grades

A grade of incomplete (I) will be given only in unusual circumstances. To receive an "I" grade, a written request must be submitted prior to December 1, and approved by the instructor. The request must describe the circumstances, along with a proposed timeline for completing the course work. Submitting a request does not ensure that an incomplete grade will be granted. If granted, you will be required to fill out and sign an "Incomplete Contract" form that will be turned in with the course grades. Any requests made after the course is completed will not be considered for an incomplete grade.

Attendance Policy

Attendance is not mandatory. However, students are expected to attend in-person lectures and participate to the discussions to succeed in the course.

Academic Integrity

Any student found cheating in any way on the exam, class project or any other assignment will fail the class and be reported to the dean.

Nondiscrimination Statement

Purdue University is committed to maintaining a community that recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. Link to Purdue's nondiscrimination policy statement.

Accessibility

Purdue University is committed to making learning experiences accessible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let the instructor know to discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247. If you have a letter of accommodation from the disability resources center (DRC), please send it to Prof. Murat Kocaoglu.

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructor via email. You are expected to read your @purdue.edu email on a frequent basis.

See emergency plans for Hampton Hall building with your Purdue credentials:
https://www.purdue.edu/ehps/emergency_preparedness/bep/HAMP-bep.html

In the Event a Student is Quarantined/Isolated

If a student is quarantined and unable to physically participate in the course, the instructor will take the necessary steps for them to complete the course remotely to the best of his abilities. This involves, but is not limited to, having the student present remotely, take the midterm at home and providing remote office hours.

Classroom Guidance Regarding Protect Purdue

Any student who has substantial reason to believe that another person is threatening the safety of others by not complying with Protect Purdue protocols is encouraged to report the behavior to and discuss the next steps with their instructor. Students also have the option of reporting the behavior to the Office of the Student Rights and Responsibilities. See also Purdue University Bill of Student Rights and the Violent Behavior Policy under University Resources in Brightspace.

Basic Needs Security

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. There is no appointment needed and Student Support Services is available to serve students 8 a.m.-5 p.m. Monday through Friday. Considering the significant disruptions caused by the current global crisis as it related to COVID-19, students may submit requests for emergency assistance from the Critical Needs Fund.

Mental Health Statement

- **If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack.** Sign in and find information and tools at your fingertips, available to you at any time.
- **If you need support and information about options and resources**, please see the Office of the Dean of Students for drop-in hours (M-F, 8 am- 5 pm).
- **If you're struggling and need mental health services**: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office of the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Wellness

TaskHuman offers private, real-time, on-demand, 1-on-1 video calls with wellness coaches covering over 800+ topics such as anxiety, mindfulness, reducing stress, clean eating, time management, in-home workouts, relationship tensions, financial issues, spiritual guidance and many more. You can access these wellness coaches from around the world 24/7. The College of Engineering has an exclusive agreement with TaskHuman which gives you FREE and UNLIMITED access to these resources. Over 3,200 calls have been made by College of Engineering students, staff, and faculty so far with an average satisfaction rating of 4.89/5. Learn more here:
https://engineering.purdue.edu/ECE/TaskHuman

Course Schedule (Tentative)

This is a new course. The instructor can make adjustments to the coverage time of different topics based on his interactions with the students and in-class impressions.

Week	Date	Topic
1	8/24	Introduction, A Brief History of Causality, Independence, Conditional Independence, Independence Models
1	8/26	Graphoid and Semi-graphoid Axioms, Undirected and Directed Graphs as Dependency Models
2	8/31	Bayesian Networks, Factorization d-separation, Global Markov Property, Local Markov Property
2	9/2	Causal Graphs, doing vs. seeing Interventions and Causal Effect Causal Markov Condition Interventional Distributions, do-operator, Truncated Factorization Formula
3	9/7	Structural Causal Models, Causal Bayesian Networks Back-door criterion, Front-door criterion Inverse-propensity Weighing Do Calculus
3	9/9	Do Calculus (cont'd) Presence of Latent Variables c-components
4	9/14	ID Algorithm Soundness and Completeness
4	9/16	Learning Causal Graphs (no latents) Observational Equivalence Class, Essential Graph
5	9/21	Midterm [Material covered until the end of do-calculus]
5	9/23	Constraint-based Learning, Faithfulness Assumption PC Algorithm
6	9/28	Score-based Learning GES Algorithm
6	9/30	Learning Causal Graphs with Latent Variables Ancestral Graphs Maximal Ancestral Graphs
7	10/5	Observational Equivalence Class with Latent Variables Inducing paths, Discriminating paths Partial Ancestral Graphs, FCI Algorithm
7	10/7	Bivariate Causal Discovery Linear Models, Additive Noise Models

		Independence of Cause and Mechanism Entropic Causality
8	10/12	OCTOBER BREAK
8	10/14	Experimental Design for Causal Discovery Challenges Graph Theory Basics
9	10/19	Connections to Graph Coloring Separating Systems and Graph Separating Systems
9	10/21	Interventional Equivalence Classes, Learning I-MECs (no latents) and I-PAGs (with latents), Open Questions
10	10/26	Introduction to Counterfactuals
10	10/28	Paper presentations
11	11/2	Paper presentations
11	11/4	Paper presentations
12	11/9	Paper presentations
12	11/11	Paper presentations
13	11/16	Paper presentations
13	11/18	Project presentations
14	11/23	Project presentations
14	11/25	THANKSGIVING
15	11/30	Project presentations
15	12/2	Project presentations
16	12/7	Project presentations
16	12/9	Project presentations