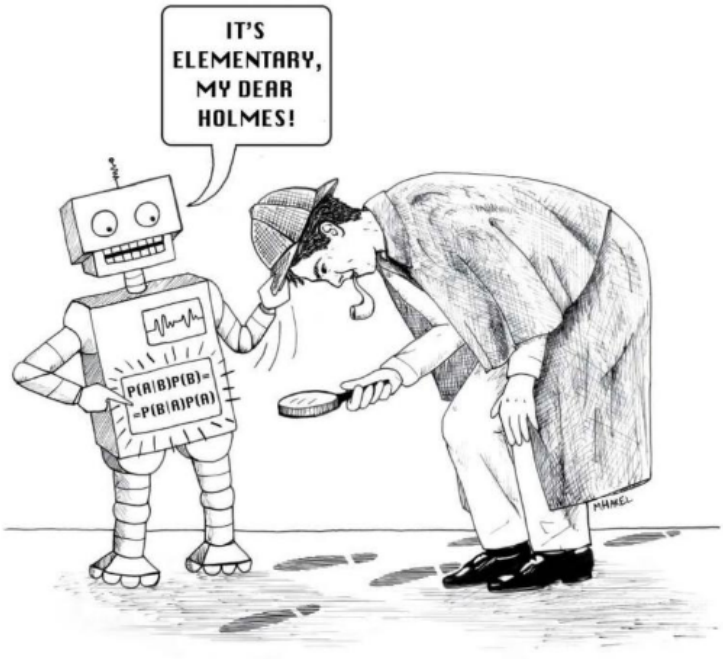
Habib University
shaping futures

Probabilistic Graphical Models

CS 452 L1
Fall Semester 2024



Sherlock Holmes meets his modern counterpart, a robot equipped with a Bayesian network. Both are tackling the question of how to infer causes from observations. The formula on the computer screen is Bayes's rule.

(Source: The Book of Why by Judea Pearl, Drawing by Maayan Harel.)

"As far as the laws of mathematics refer to reality, they are not certain, as far as they are certain, they do not refer to reality". Albert Einstein, 1921

Course Information

Start Date	End Date	Class Location	Meeting Time
Aug 19 2024	Dec 03 2024	W-321	Tues Thurs (08:30 AM-09:45 AM)

Hardware/Software Prerequisites (if any): Computer system to do assignments and projects.
Content Area: This course fulfills the requirements of a CS Elective or a Free elective and can be counted as a CS elective toward the CS minor. Enrollment in the course is subject to meeting the prerequisites.

Prerequisite Courses: EE/CE 354/361 Introduction to Probability and Statistics, and CS/MATH 113 Discrete Mathematics.

Instructor Information

Instructor: Syeda Saleha Raza
Office Location: C-212
Email: saleha.raza@sse.habib.edu.pk
Office Hours: Mon/Tue: 2:00 - 3:00 pm, Thu: 1:00 - 2:00 pm

Course Description

Logic and reasoning have laid the foundation of AI. The quest to effectively acquire and represent human knowledge in a form suitable for machine reasoning and inference has long been a key area of AI. While recent years have seen a surge in machine learning based approaches, the domain of knowledge-based representation and reasoning has retained its significance. This course aims to equip students with the fundamentals of this field, highlighting the pivotal role of causality and causal relationships in understanding real-world phenomena, which can be effectively captured through probabilistic graphical models such as Bayesian Networks.

Course Aims

This course exposes students to knowledge-based representation and reasoning mechanisms, and equips them to build probabilistic graphical models that account for uncertainties inherent in real-world scenarios. With a primary focus on Bayesian Networks, students will develop proficiency in building Bayesian networks and will understand the role of causal relationships in modeling real-world scenarios. The course will go deep into the techniques for inference and belief propagation in these networks and will also cover methods to learn these structures from past data. This course will enable the students to analyze and compare knowledge-based approaches to machine learning methodologies, discerning the respective strengths, limitations, and potential synergies between the two paradigms.

Course Learning Outcomes (CLOs)

CLO1	Model real-world scenarios in the form of Bayesian networks and some of its variants and perform inference.	
CLO2	Learn different exact and approximate methods for belief propagation in graphical models.	
CLO3	Utilize data-driven methods to learn Bayesian Networks from available data	
CLO4	Compare and contrast knowledge-based vs machine learning based approaches and their respective strengths and limitations. Identify research challenges and potential research direction in the field.	

Mode of Instruction

The class will be conducted twice a week for 75 minutes. Students should expect to work for at least 5-6 hours per week outside of the scheduled class for this course.

Engagement & Participation Rules

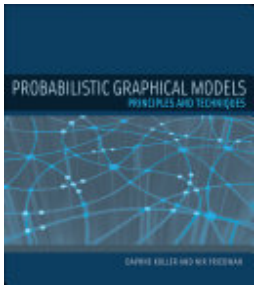
There will be multiple engagement opportunities during the course in the form of assignments, presentations, quizzes, discussions and open questions. Students are required to participate in all of these activities/assessments. Student engagement in the course will be measured through their participation and performance in:

1. quizzes

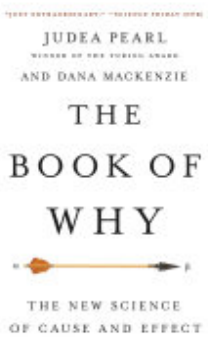
2. timely submission of assignments
3. participation in class

Students are highly encouraged to participate in class discussions. The instructor promotes to prevail a lighter class environment that encourages Q&A, discussions and feedback while ensuring integrity and respect towards each participant. No disrespectful behaviour will be tolerated.

Required Texts and Materials

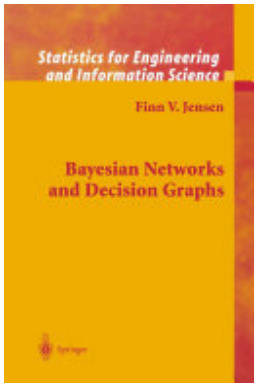


Probabilistic Graphical Models
ISBN: 9780262258357
Authors: Daphne Koller, Nir Friedman
Publisher: MIT Press
Publication Date: 2009-07-31



The Book of Why
ISBN: 9780465097616
Authors: Judea Pearl, Dana Mackenzie
Publisher: Basic Books
Publication Date: 2018-05-15

Optional Materials



Bayesian Networks and Decision Graphs
ISBN: 9781475735024
Authors: Thomas Dyhre Nielsen, FINN VERNER JENSEN
Publisher: Springer Science & Business Media
Publication Date: 2013-06-29

Assessments

Assignments (2)	13%
Quizzes (4)	12%
Midterm Exam	15%
Presentation	10%
Project	15%
Paper	15%
Final Exam	20%

The presentation will be done in pairs and will be based on recent trends and research challenges in the field of Probabilistic Graphical Models.

The paper is based on the problem addressed in the project and will be written in standard IEEE research paper format with major sections of Introduction, literature review, Methodology, and Experiments & Results. The total points of Project + Paper (35%) are divided into following components.

Project Specification	02
Literature Review	05
Interim Updates	04
Final Demo	09
Paper	10

Grading Scale

Letter Grade	GPA Points	Percentage
A+	4.00	[95-100]
A	4.00	[90-95)
A-	3.67	[85-90)
B+	3.33	[80-85)
B	3.00	[75-80)
B-	2.67	[70-75)
C+	2.33	[67-70)

Letter Grade	GPA Points	Percentage
C	2.00	[63-67)
C-	1.67	[60-63)
F	0.00	[0, 60)

Note: [a, b) is a range of numbers from a to b where a is included in the range and b is not.

Late Submission Policy

- Students are required to adhere to the timelines and submit their work promptly.
- If a student encounters a genuine problem that affects his performance in the assessment, he should discuss the matter with the instructor in advance to request an accommodation. No last-minute requests for extensions will be entertained.
- Late submissions without a genuine reason will incur a 10% grade reduction penalty for every 24-hour delay.

Week-Wise Schedule (Tentative)

FALL 2024 WEEKLY SCHEDULE

***(Subject to final approval from the Academic Council)**

Week	Description	Readings	Assignments
Week - 1 August 19 – 23, 2024	Course Overview, Causality, Causation vs Correlation, The ladder of Causation, Knowledge-based vs Machine learning based approaches.	Pearl, Ch. 1	
Week - 2 August 26 – August 30, 2024	Probabilities - Recap, Joint Probability Distribution, Conditional, Marginal probabilities, Bayes' theorem, Chain Rule Bayesian Networks (BN), DAG, Conditional probability table, Markov property		
Week - 3 September	d-seperation, Types of connections		Ass1 out

2 – 6, 2024	(Serial, Converging, Diverging) and their behaviors Case Studies: Modelling real-world cases using BN, Using GeNie to model Bayesian Networks		
Week - 4 September 9 – 13, 2024	Challenges in Knowledge Acquisition, Variants – Noisy-OR models, CAST Logic/Influence Net		Quiz 1
Week - 5 September 16 – 20, 2024	Temporal Models, Dynamic Bayesian Networks 12th Rabi-ul-Awwal†‡: September 16, 2024		Ass1 due
Week - 6 September 23 – 27, 2024	Project Discussions		Quiz 2 Project Specifications due
Week - 7 September 30 – October 4, 2024	Midterm Exam		Midterm Exam
Week - 8 October 7 – 11, 2024	Belief Propagation in a singly-connected network Inference by Variable elimination		Literature Review due
Week - 9 October 14 – 18, 2024	Inference by graph decomposition		Quiz 3 Ass2 out
Week - 10 October 21 – October 25, 2024	Inference by approximate methods and Sampling techniques		
Week - 11 October 28 – November 1, 2024	Parameter Learning		Ass2 due
Week - 12 November 4 – 8, 2024	Parameter Learning		Quiz 4
Week – 13 November 11 – 15, 2024	Structure Learning, Bayesian Score, Faithfulness of DAG, Evolving a DAG		Interim Project Updates
Week - 14 November 18 – 22, 2024	Structure Learning, Bayesian Score, Faithfulness of DAG, Evolving a DAG		
Week – 15 November 25 – 29, 2024	Presentations on current trends and research directions in Bayesian networks/PGM such as:		Presentations

	• Deep learning integration • Explainable AI and Bayesian networks • Exact inference methods using parallel computing • Gated Bayesian networks		
Week – 16 December 2 – 6, 2024	Project Presentations		Project due, Final Demo, and Paper due
December 10 – 14 & 16, 2024	Final Exam		

Notes:

* The University reserves the right to correct typographical errors or to adjust the Academic Calendar at any time it

deems necessary.

† Subject to the sighting of moon.

‡ No Class(es).

§ University's Examination Policy is available in the Academic Policies folder on the Faculty/Staff Portal.

Attendance Policy

You are expected to attend all classes (on-site or online). Attendance will be formally recorded on PeopleSoft. We understand that there can be unanticipated, and unavoidable situations in which you may sometimes be unable to attend. A slack of 15% is provided, i.e. you may miss up to 15% of the classes for genuine reasons. Missing any more is tantamount to an irreparable loss in learning for the course, and you will be automatically dropped.

Final Exam Policy

An in-person, paper-based final exam will be held during the final exam week.

Academic Integrity

Each student in this course is expected to abide by the Habib University Student Honor Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work.

Scholastic dishonesty shall be considered a serious violation of these rules and regulations and is subject to strict disciplinary action as prescribed by Habib University regulations and policies. Scholastic dishonesty includes, but is not limited to, cheating on exams, plagiarism on assignments, and collusion.

a. Plagiarism: Plagiarism is the act of taking the work created by another person or entity and presenting it as one's own for the purpose of personal gain or of obtaining academic credit. As per University policy, plagiarism includes the submission of or incorporation of the work of others without acknowledging its provenance or giving due credit according to established academic practices. This includes the submission of material that has been appropriated,// bought, received as a gift, downloaded, or obtained by any other means. Students must not, unless they have been granted permission from all faculty members concerned, submit the same assignment or project for academic credit for different courses.
b. Cheating: The term cheating shall refer to the use of or obtaining of unauthorized information in order to obtain personal benefit or academic credit.
c. Collusion: Collusion is the act of providing unauthorized assistance to one or more person or of not taking the appropriate precautions against doing so.

All violations of academic integrity will also be immediately reported to the Student Conduct Office.

You are encouraged to study together and to discuss information and concepts covered in lecture and the sections with other students. You can give "consulting" help to or receive "consulting" help from such students. However, this permissible cooperation should never involve one student having possession of a copy of all or part of work done by someone else, in the form of an e-mail, an e-mail attachment file, a diskette, or a hard copy.

Should copying occur, the student who copied work from another student and the student who gave material to be copied will both be in violation of the Student Code of Conduct.

If you wish to use generative-AI tools to complete any of your assessments, you must first obtain permission from your course instructor. AI generated work will not be accepted in all classes or even

all assessments. The instructor's permission is required. If the permission is granted, you should declare its use and properly cite the source of the generated content. Failing to identify AI written or assisted work is academic dishonesty and will be treated as any case of plagiarism by the university.

The principle for academic integrity is that your submissions must be substantially your own work and that any work that is not originally your thought must be identified and credited. If the use of AI tools is prohibited in the course, respect the rules and do not use these tools for assessments. The fundamental purpose of assessment is to learn, synthesize information and explain new connections and interpretations that arise from your secondary research. Be aware that unauthorized use of AI tools for assessments can result in a conduct case being filed. This can have serious consequences for your academic standing and future career opportunities.

During examinations, you must do your own work. Talking or discussion is not permitted during the examinations, nor may you compare papers, copy from others, or collaborate in any way. Any collaborative behavior during the examinations will result in failure of the exam, and may lead to failure of the course and University disciplinary action.

Penalty for violation of this Code can also be extended to include failure of the course and University disciplinary action.

Program Learning Outcomes (For Administrative Review)

Upon graduation, students will have the following abilities:

- PLO 1: Theoretical Computer Science: recall and apply foundational principles of computer science.
- PLO 2: : Application Development: build software systems of varying complexity in light of fundamental computer science principles and any other constraints.
- PLO 3: Analysis and Design: perform technical analysis and design using core computing and mathematical knowledge.
- PLO 4: Systems: apply the knowledge of computing systems.
- PLO 5: : Research and Exploration: develop expertise in and contribute to a given sub-field of computing by drawing upon a strong foundation in the fundamentals of computer science and mathematics to solve real-life problems.

- PLO 6: Problem Solving: identify and analyze problems and propose effective computing-based solutions.
- PLO 7: Practical Exposure: make effective use of current tools, technologies, and good industry practices.
- PLO 8: Responsible Citizenship: conduct their computing practice in a manner that is ethical and socially responsible and corresponds to their distinct sense of identity and service to the community.
- PLO 9: Self-Learning: continuously adapt their skills to the changes taking place around them.
- PLO 10: Design Thinking: apply design thinking principles to the design of a solution.
- PLO 11: Multi-disciplinarity: incorporate knowledge and input from multiple disciplines.
- PLO 12: Communication and Teamwork: communicate and function effectively as a member or a leader of a variety of teams.

Program Learning Outcomes (PLOs) mapped to Course Learning Outcomes (CLOs)				
	CLOs of the course are designed to cater following PLOs: **PLO 1: Theoretical Computer Science** **PLO 3: Analysis & Design** **PLO 5: Research and Exploration** **PLO 9: Self-learning** **PLO 12: Communication and Teamwork**			
	Distribution of CLO weightage for each PLO			
	CLO 1	**CLO 2**	**CLO 3**	**CLO 4**
PLO 1				
PLO 3				
PLO 5				
PLO 9				
PLO 12				

Mapping of Assessments to CLOs

Assignments	CLO #01	CLO #02	CLO #03	CLO #04
HW 1	✓			
HW 2		✓		✓
Quiz 1	✓			
Quiz 2		✓		
Quiz 3			✓	
Quiz 4				✓
Presentation				✓
Project	✓		✓	✓
paper	✓			✓
Final Exam	✓	✓	✓	✓

Recording Policy

Only asynchronous and synchronous online sessions will be conducted and recorded via MS Teams. Link to the recordings will be available to all students on Canvas Learning Management System.

Accommodations for Students with Disabilities

In compliance with the Habib University policy and equal access laws, I am available to discuss appropriate academic accommodations that may be required for student with disabilities. Requests for academic accommodations are to be made during the first two weeks of the semester, except for unusual circumstances, so arrangements can be made. Students are encouraged to register with the Office of Academic Performance to verify their eligibility for appropriate accommodations.

Inclusivity Statement

We understand that our members represent a rich variety of backgrounds and perspectives. Habib University is committed to providing an atmosphere for learning that respects diversity. While working together to build this community we ask all members to:

- share their unique experiences, values and beliefs
- be open to the views of others

- honor the uniqueness of their colleagues
- appreciate the opportunity that we have to learn from each other in this community
- value each other’s opinions and communicate in a respectful manner
- keep confidential discussions that the community has of a personal (or professional) nature
- use this opportunity together to discuss ways in which we can create an inclusive environment in this course and across the Habib community

Office Hours Policy

Every student enrolled in this course must meet individually with the course instructor during course office hours at least once during the semester. The first meeting should happen within the first five weeks of the semester but must occur before midterms. Any student who does not meet with the instructor may face a grade reduction or other penalties at the discretion of the instructor and will have an academic hold placed by the Registrar’s Office.