University of South Carolina
Department of Computer Science and Engineering
College of Engineering and Computing

Bayesian Networks and Decision Graphs
CSCE 582 and STAT 582 Section 001 – Location: SWGN 2A22 – Spring 2024

Instructor	Dr. Marco Valtorta
Course Websites	https://cse.sc.edu/~mgv/csce582sp24/index.html (main), https://blackboard.sc.edu (lectures), https://dropbox.cse.sc.edu (assignments)
Phone	(office) 803-777-4641; (mobile) 803-446-3225
Email	mgv@cse.sc.edu
Office location	INNOVA 2269.
Meeting Times	TTh 1625-1740.
	Office Hours: Tuesday 1030-noon and Thursday 1100-1230. Please email mgv@cse.sc.edu before coming, if possible, or to schedule an alternate meeting time either in person or online.

NOTE: I check email very frequently and usually respond within a few hours. Email is the preferred and strongly recommended means of communication with the instructor.

Academic Bulletin Description:
CSCE 582 Bayesian Networks and Decision Graphs. (Cross-listed Course: STAT 582) (Credits:3) (Prerequisites: CSCE 350; STAT 509 or STAT 515) Normative approaches to uncertainty in artificial intelligence. Probabilistic and causal modeling with Bayesian networks and influence diagrams. Applications in decision analysis and support. Algorithms for probability update in graphical models.

Carolina Core Learning Outcome: None.

Course Learning Outcomes
Upon successful completion of this course, students should be able to:

- Design Bayesian network models.
- Design decision trees and simple influence diagrams.
- Use the Hugin Bayesian network and influence diagram shell.

Graduate students will also be able to demonstrate the ability to evaluate an important paper from the peer-reviewed literature on uncertainty in artificial intelligence and assess its contribution by writing a report and/or preparing a presentation and/or writing a software program.

Course Overview
This course will be in person.

• Student-to-Instructor (S2I) Interaction: Students will listen/view lectures and interact with the professor in the classroom. The professor will hold online office hours in his office, post announcements on the course websites, and provide individual feedback to students through the CSE dropbox website and email.

• Students-to-Student (S2S) Interaction: Students will engage in discussions through a discussion forum in Blackboard.

• Student-to-Content (S2C) Interaction: Students will engage with course content by completing assignments and reports and (possibly) participating in video conference or in-person meetings.

The instructor will reply to all feedback in a reasonable amount of time; the same is expected of the students. Specifically,

• Communication: Responses to email communication and questions will be provided within 48 hours.

• Assignment and Test Grading Grades for assignments will be returned within one week of due date.

• All assignments are due before the beginning of class. A 10% deduction will be given to late submissions that are turned in before the beginning of the next class. No credit will be given for assignments that are turned in after the beginning of the next class.

Required Textbook:
Jensen, Finn V. and Thomas D. Nielsen. *Bayesian Networks and Decision Graphs, 2nd ed*. New York: Springer-Verlag, 2007 (ISBN-10 0-387-68281-3; ISBN-13: 978-0-387-68281-5) (Approximately $100 at amazon.com or at the bookstore. This text is referred to as [J07] or [J] in this course.)
All readings/materials comply with copyright/fair use policies.
The library provides free online access (with copy/print restrictions) to this textbook.

Recommended Textbooks:

Other recommended books on the topic are:

- Robert G. Cowell, A. Philip Dawid. Steffen L. Lauritzen, and David J. Spiegelhalter. *Probabilistic Networks and Expert Systems*. New York: Springer, 1999 (ISBN 0-387-98767-3).
- Adnan Darwiche. *Modeling and Reasoning with Bayesian Networks.* Cambridge, UK: Cambridge University Press, 2009 (ISBN 978-0-521-88438-9).
- Daphne Koller and Nir Friedman. *Probabilistic Graphical Models: Principles and Techniques*. Cambridge, MA: The MIT Press, 2009 (ISBN 978-0-262-0139-2).
- Timo Koski adn John M. Noble. *Bayesian Networks: An Introduction*. Chichester, UK: Wiley, 2009 (ISBN 978-0-470-74304-1).

- Uffe B. Kjaerulff and Anders L. Madsen. *Bayesian Networks and Influence Diagrams: A Guide to Construction and Analysis*. New York: Springer-Verlag, 2008 (ISBN 978-0-387-74100-0).
- Kevin B. Korb and Ann E. Nicholson. *Bayesian Artificial Intelligence*, 2nd ed. London: Chapman & Hall and CRC Press, 2011 (ISBN 978-1-4398-1591-5). (First edition: London: Chapman & Hall and CRC Press, 2004, ISBN 1-58488-387-1.)
- Jensen, Finn V. *Bayesian Networks and Decision Graphs*. New York: Springer-Verlag, 2001 (ISBN 0-387-95259). (This text is referred to as [J01].)
- Jensen, Finn V. *An Introduction to Bayesian Networks*. New York: Springer-Verlag, 1996 (ISBN 0-387-91502-8). (This text is referred to as [J96].)
- Richard E. Neapolitan. *Probabilistic Reasoning in Expert Systems: Theory and Algorithms*. New York: Wiley, 1990 (ISBN 0-471-61840-3).
- Judea Pearl. *Probabilistic Reasoning in Intelligent Systems*. San Francisco: Morgan-Kaufmann, 1988 (ISBN 0-934613-73-7).
- Judea Pearl. *Causality: Models, Reasoning, and Inference, 2nd ed*. Cambridge, UK: Cambridge University Press, 2009 (ISBN 0-521-77362-8).

Technology and Required Course Materials:

- Students must view PowerPoint and pdf lectures/presentations.
- Students must read chapters in the required textbook.
- Students must have access to a computer with Internet access to check the course website maintained by the instructor (https://cse.sc.edu/~mgv/csce582sp21), the departmental dropbox (https://dropbox.cse.sc.edu/login), and Blackboard.
- Students must have the ability to create, save and upload programs to the departmental dropbox.
- Students must have access to a computer with Hugin installed. Note that the departmental Linux computers have the current Hugin version installed. The instructor will make older versions of Hugin available for use on student computers under Windows.

Course Purpose and Overall Structure of the Course:

Bayesian networks are graph-based representations of probability distributions. They are used to model and reason efficiently, by exploiting conditional and unconditional independence relationships, in domains where naïve approaches are impossibly complex. Decision graphs extend Bayesian networks by representing actions and utilities and include decision trees and influence diagrams. Bayesian networks, invented almost 40 years ago, and decision graphs have since been applied in many fields, including medical diagnosis, troubleshooting of complex artifacts, intelligent and active user interfaces, image recognition, intelligence analysis, monitoring of power plants, reliability analysis, coding, forensics, and genetics. Hidden Markov models and Kalman (Thiele) filters were shown to be special cases of Bayesian networks, an insight closely connected to the development of dynamic (time-repeating) Bayesian networks. From an algorithmic perspective, Bayesian networks have proven to be a fertile ground for the use of graph algorithms, non-serial dynamic programming, and other advanced techniques.

This course is foundational. It concentrates on modeling and use of decision analysis principles. Algorithms for belief updating (especially variable elimination and Jensen's version of the Lauritzen-Spiegelhalter algorithm, but also stochastic simulation) are discussed to some depth, but advanced topics on algorithmic issues are left out. It is my hope that a student who successfully completes this course will both be able to use decision analytic tools such as Hugin well and be well prepared for advanced graduate courses on other kinds of graphical probabilistic models and, e.g., data mining.

Technical Support:

Blackboard Help (http://ondemand.blackboard.com/students.htm)

If you have problems with your computer or Blackboard, please contact the IT Technology Support Service Desk at 803.777.1800 (open Monday – Friday from 8:00 AM – 6:00 PM), or use one of the online support options described at https://www.sc.edu/about/offices_and_divisions/division_of_information_technology/about_us/news/2020/tech_support.php. If you have problems with the departmental dropbox, please contact the instructor. The departmental and college computers are always available online and include the required Hugin software shell.

Late Work/Make-Up Policy:

Late work is accepted with a 10% penalty until the beginning of the class after the due date. The clock on your computer may be different than that clock on the departmental dropbox. If the clock is different by one minute, you might be subject to the late homework penalty. Plan accordingly. I recommend that you submit your assignments well before the deadline.

Extra Credit:

Extra credit assignments will not be assigned.

Attendance Policy:

There is no penalty for missing classes. Students are very strongly encouraged to attend every class and are responsible for making up the material covered in missed classes. **I estimate that one missed class will result in at least three hours of extra work outside of class.**

Ability to Work at Your Own Pace:

The course builds upon the material in an incremental fashion. It is very difficult to catch up if several classes are missed.

The course syllabus includes an accessibility statement that encourages students with disabilities to register with the Office of Student Disability services; should a student with a registered disability enroll in the course, the professor will work with the Office to make any additional accommodations appropriate to that student's needs.

Course Communications:

You are required to use your *UofSC email account* throughout this course. I will be communicating with you regarding grades and assignments. I will reply to emails within 24 hours and will provide feedback on assignments within 48 hours. When sending an email, please include a *detailed subject line*. Additionally, make sure you reference the course (CSCE 582 or STAT 582) and sign the email with your name. Begin these emails with a proper salutation (e.g., Dear Dr. Valtorta, Hello Dr. Valtorta, and Good evening Dr. Valtorta). Starting an email without a salutation or a simple "Hey" is not professional or appropriate. Of course, if the emails evolve into a thread with rapid exchanges, e.g., when discussing a programming issue, you may omit the salutation.

Grades Will Be Calculated as Follows.

The course grade will be based on homework, including Bayesian network development exercises, a midterm exam, and a final exam.
The grading policy for undergraduate students is as follows:

- Midterm Exam: 20%
- Homework assignments (including network development exercises using Hugin): 45%
- Final Exam: 35%

The final exam for graduate students will include an extra question and be graded more strictly. Graduate students are required to evaluate an important paper from the peer-reviewed literature on uncertainty in artificial intelligence and assess its contribution by writing a report and/or preparing a presentation and/or writing a software program. Graduate students are **required** to do the extra work, and a student may lose up to one letter grade for missing or unsatisfactory extra work. Your final grade is based on the total points you have earned over the course. Individual homework assignments are not curved, and all points for all assignments are weighted equally. The numeric scores are translated to letter grades as follows:
[90-100] = A, [87-90) = B+, [80-87) = B, [77-90) = C+ ,[70-77) = C, [67-70) = D+ [60-67) = D, [0-60) = F
However, a combined score of 60% on the midterm and the final is required to obtain a C in the course; a student who would otherwise obtain a C or better in the course may obtain at most a D+ if his or her combined score on the midterm and final is less than 60%; this percentage is computed as a weighted average of the percentages in midterm and final, with the final and midterm weighted according to their percentage contribution to the final score, i.e., in 20/35 ratio. Simple grading rubrics will be posted on the instructor's course website under "points per assignment." You are encouraged to review the rubric before starting an assignment.

Warning.: Please **do not plagiarize**. I normally do not use an automated system to detect plagiarism, but this may change at any time. See the section on Academic Honesty below for more.

Disability and Other Student Support Services:

Students with disabilities should contact the Student Disability Resource Center (SDRC). The contact information is below:

1705 College Street
Close-Hipp, Suite 102
Columbia, SC 29208
Phone: 803-777-6142

Fax: 803-777-6741
Email: sadrc@mailbox.sc.edu
Web:
https://sc.edu/about/offices_and_divisions/student_disability_resource_center/

These services can aid with accessibility and other issues to help those with disabilities be more successful in the course. Additionally, students with disabilities should review the information on the SDRC website and proactively communicate with the professor before or during the first week of class.

The following other academic support services and resources may help you be more successful in the course as well.

Library Services (http://www.sc.edu/study/libraries_and_collections)
Writing Center (http://artsandsciences.sc.edu/write/)
Student Technology Resources
(http://www.sc.edu/about/offices_and_divisions/division_of_information_technology/)

Academic Honesty:

Every student has a role in maintaining the academic reputation of the university. It is imperative that you refrain from engaging in plagiarism, cheating, falsifying your work and/or assisting other students in violating the Honor Code.

Plagiarism/Cheating, as defined in the code of student Academic Responsibility, will **result in a grade penalty (up to course failure)** in this course in addition to any penalty/penalties exacted by the appropriate Academic Dean and the University Honor Council to whom all offenses will be reported. The Student Conduct and Academic Integrity website (https://sc.edu/about/offices_and_divisions/student_conduct_and_academic_integrity/index.php) contains information and links to relevant policies and procedures; particularly important is policy STAF 6.25 (Academic Responsibility—The Honor Code), which, among other things, describes what constitutes plagiarism and cheating, and describes the possible sanctions. You are responsible for reading and abiding by these policies and procedures.

You must save files on a USB drive or other secure area. Many of you are familiar with github from other courses or have used other version control or code management systems (e.g., bitbucket). The programming assignments in this course are rather short and do not build on each other, so you are not required to use such a system but doing so may be useful for creating an electronic portfolio as you start your careers. Do not save your work on a public computer or library computer as others will have access to your work. You should have a back-up of all your files in another location. Submitting someone else's work is cheating and against the Carolina Code. Cheating will result in penalties**.** All parties will also be referred to the Office of Academic Integrity for additional retribution.

It is very good to study in groups. In fact, there is evidence that group studying is a predictor of success, at least in early college mathematics courses. Some of you may enjoy studying in groups! You are therefore encouraged to discuss the material you study, but you must do your homework individually, unless an assignment is explicitly designated as a team assignment. The **minimum** grade penalty for a violation will be a zero on the work involved. In addition, an honor code violation will be subject to the sanctions described in the USC Community Handbook and Policy Guide. The following paragraph, written by emeritus professor Duncan Buell, clarifies the distinction between "learning from a discussion" and "turning in someone else's work": If, after having participated in a group activity, you can walk away, put the books down, have lunch, and then come back afterwards to re-create from your own head the material and techniques you discussed as a group, then you can legitimately say that you have learned from the group but the work you turn in is your own.

CSCE 582 --- SPRING 2024
TIME ALLOCATION FRAMEWORK

WEEK	TOPIC	SOURCE
1 (1/9,11)	Probability and Reasoning	Chs.1 and 2 [J[; instructor's slides
2 (1/16,18)	Probability and Reasoning	Chs.1 and 2 [J[; instructor's slides
3 (1/23,25)	Causal and Bayesian Networks	Ch.2 [J]
4 (1/30,2/1)	Causal and Bayesian Networks	Ch.2 [J]
5 (2/6,8)	Building Models: Capturing the Structure and Determining the Conditional Probabilities	Sections 3.1 & 3.2 [J]
6 (2/13,15)	Building Models: Capturing the Structure and Determining the Conditional Probabilities	Sections 3.2 and 3.3 [J] and notes on the stratum method
7(2/20,22)	Building Models: Advanced Modeling Methods and Special Features	Sections 3.3 and 3.4 [J]
8 (2/27,2/29)	Review (if time permits) and Midterm	Sections 3.3 and 3.4 [J]
3/5,7	Spring Break	
9 (3/12,14)	Belief Updating in Bayesian Networks: The Junction Tree Method	Ch.4 [J96] & Ch. 4 [J]
10 (3/19,21)	Belief Updating in Bayesian Networks: Stochastic Simulation and Loopy Belief Propagation	Sections 4.7-4.8 [J] & Section 4.6 [J96]
11 (3/26,28)	Graphical Languages for Decision Problems	Ch.9 [J]
12 (4/2,4)	Graphical Languages for Decision Problems	Ch.9 [J]
13 (4/9,11)	Graphical Languages for Decision Problems	Ch.9 [J]
14 (4/16,18)	Review (if time permits) and Graduate Student Presentations	
April 30	Final Exam: Tuesday, April 30, 12:30 p.m.	According to the University Exam Schedule

The time allocation framework is subject to review and revision during the course.
Homework assignments will be provided during the course.
The Academic Calendar for spring 2024 is at https://www.sc.edu/about/offices_and_divisions/registrar/academic_calendars/2023-24_calendar.php. Spring break is from March 3-10 (Sunday-Sunday). The last day to withdraw without a grade of WF being recorded is March 25 (Monday). Reading day is April 23 (Tuesday). The final exam schedule is at https://www.sc.edu/about/offices_and_divisions/registrar/final_exams/index.php.
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