Learning Guide Unit 6

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Book:	Learning Guide Unit 6		

Description

Learning Guide Unit 6

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Overview

Unit 6: Reasoning Under Uncertainty

Topics:

- Review of Basic Probability
- Random Variables and Probability Distributions
  - Axioms of Probability
  - Conditional Probability
  - Bayes' Theorem
- Conditional Independence
- Belief Networks
- Hidden Markov Models

Learning Objectives:

By the end of this Unit, you will be able to:

1. Examine Conditional Probability based upon Independent and Dependent Events.
2. Identify examples of knowledge representations for reasoning under uncertainty.
3. Examine how Belief networks are used to model uncertainty in a domain using directed acyclic graph.

Tasks:

- Peer assess Unit 5 Programming Assignment
- Read the Learning Guide and Reading Assignments
- Participate in the Discussion Assignment (post, comment, and rate in the Discussion Forum)
- Complete an entry in the Learning Journal
- Take the Self-Quiz
- Take the Graded Quiz

Introduction

In this unit, we will review the basics of probability theory. In the previous unit, we examined how propositional logic is used to reason about and make decisions when there is complete knowledge about an environment. On the other hand, there are many situations where agents must operate in open-world environments where complete knowledge of the environment is not possible. In environments where decisions must be made based upon incomplete information, we turn to probability theory to help guide decisions.

Our text defines probability theory as the study of how knowledge affects belief. We need to define the idea of belief in this context. In the previous unit, we examined the use of facts, knowledge of the world that was expressed as true or false. In the close world system of propositional logic, we KNOW facts about the state of the world because such facts are finite. They specify what is known or not known in concrete, certain terms. In an open world, we cannot know everything. We may have more or less knowledge but we don't have complete knowledge so there is always an element of uncertainty.

Consider the following thought exercise. Assume that we have a room with a light in it and a light switch within the room. When we turn the light switch on, the light turns on. When we turn the switch off, the light turns off. Let's further make an assumption that the power to the switch was always on. In this situation, we have a closed system. We know the state of both the switch and the light and given the fact that the power to the light switch is always on, we KNOW that when we turn the switch on the light will be on. Of course, we can see that both the switch and the light is on. In this situation, we have complete information and because we have complete information, we KNOW the outcome of turning on the switch.

Now let's consider the same situation but the switch is in another room. From the position of the switch, we are unable to see the light in the room. In this case, if we were to turn on the switch, we can assume that the light goes on, however, we don't KNOW for sure that it did because we don't have all of the information. The switch could be for a different light rather than the one in the original room. In this situation, we do not have complete information. We must reason about the state of the light from the perspective of uncertainty. We of course could turn the switch on and then go check the state of the light. If it is on we could infer that when the switch is turned on the light is turned on, however, since we don't have complete information (such as there being a direct correlation between the light switch and the light) there is an element of uncertainty. We BELIEVE that the light switch controls the light but we don't KNOW it for certain.

Probability theory provides us with a means to measure the strength of our belief. In our light switch example, we might have a strong belief as expressed by a large probability ratio because the alternative explanations for the phenomena that we observe are remote, however, we still don't KNOW we only BELIEVE that we know how the light and switch work.

Conditional Probability

In an open world, we do not have the luxury of complete knowledge or certainty. We must rely upon an evaluation of the level of belief in a proposition that is expressed in terms of a probability of truth. These probabilities are sometimes independent of each other and may in some cases be dependent upon each other. We use Bayes' theorem to compute the probability of a proposition based upon all of the factors or axioms that are related to it.

In defining Bayes we have two definitions that are important to understand prior probability and posterior probability. A prior probability is an initial probability value obtained before any additional information is obtained. For example, a child has a 51% chance of being born male and a 49% chance of being born female. Thus the prior probability of being born male is 51%.

A posterior probability is a probability value that has been revised by using additional information. The probability that any person living on the planet selected randomly is male is slightly less than 50% for a variety of reasons such as the fact that men don't tend to live as long as women and other factors. This additional information can change the probability that 51% of the people are male.

Consider the following example:

Assume that a soccer team plays 60% of its games at night and 40% in the daytime. The team wins 55% of its night games but only 35% of its day games. You read that the team had won their last game, what is the probability that it was played at night?

Bayes' theorem can help us to determine this because we have both a prior probability (the number of games played at night) and we modify this with the probability that it will win a day or night game.

Let's denote the probability of playing night games as A and the probability of playing day games as A' such that:

P(A) = .6 - Night games
P(A') = .4 - Day games

Next, we will denote the probability of winning and losing both day and night games. We know that we win 55% of night games which means that we lose 45% of them. Further, we know we win 35% of the day games which means that we lose 65% of the day games. We denote all of these conditional probabilities as such:

P(B|A) - Probability of Winning night games =.55
P(B’|A) - Probability of losing night games =.45
P(B|A’) - Probability of Winning day games =.35
P(B’|A’) - Probability of losing day games =.65

We can then compute joint probabilities as such:

P(A) and P(B|A) - Probability of Winning night games = .6 * .55 = .33
P(A) and P(B’|A) - Probabilty of losing night games = .6 * .45 = .27
P(A’) and P(B|A’) - Probability of Wining day games = .4 * .35 = .14
P(A’) and P(B’|A’) - Probability of losing day games = .4 * .65 = .26

If you recall, what we are trying to determine is the probability that the game was played at night. We know that we want the probability that it was a night game GIVEN the fact that the game was won. This means that we are looking for P(A|B) as A is the probability the game was played at night and B the probability that the game was won as such we have P(A) = .6 and P(B|A) = .55.

$$P(A/B) = \frac{P(A)*P(B/A)}{P(B)}$$

The only thing we yet need to compute a solution to our problem is to determine the probability of B or the probability of winning a game. In order to do this, we must combine the probability of winning night games and the probability of winning day games. Since B denotes winning games (as opposed to B’ which denotes losing games), we will use both of the joint probabilities that involve winning including:

P(A) and P(B|A) - Probability of Winning night games = .6 * .55 = .33
P(A’) and P(B|A’) - Probability of Wining day games = .4 * .35 = .14

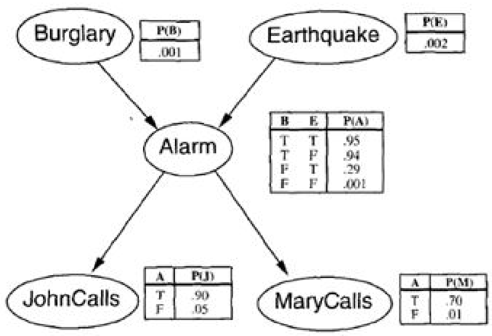
Our completed formula looks like the following and will allow us to calculate the probability that the game was played at night.

$$P(A/B) = \frac{.6*.55}{.33+.14}$$

This of course results in .702 or a 70.2% chance that the game was played at night. These kinds of conditional probabilities can be used in decision making by agents. You can imagine that there are all kinds of situations where such probabilities can be used in decision-making.

Belief Networks

Belief networks provide us with a way of visualizing the conditional probabilities between items or events. In the previous section, we determined conditional probabilities between two events winning/losing games and night/day games. This is a simple example, but in many cases, there may be multiple levels and more complexity between the items or events. In these cases, we can visually represent the relationships between events and the associated probabilities through the use of a directed acyclic graph.



The figure details a belief network. The belief network provides conditional probabilities between the alarm event and a number of other events. Each node has a conditional probability table (CPT) that gives the probability of each of its value given every possible combination of values for its parents. Burglary and Earthquake are conditionally independent and the roots of this directed acyclic graph. The alarm might be activated either by burglary or earthquake. John’s call depends on Alarm and true only if he heard the alarm. The same rule applies to Mary.

Reading Assignment

Poole, D. L., & Mackworth, A. K. (2017). *Artificial Intelligence: Foundations of computational agents*. Cambridge University Press. https://artint.info/2e/html/ArtInt2e.html

Read the following chapters:

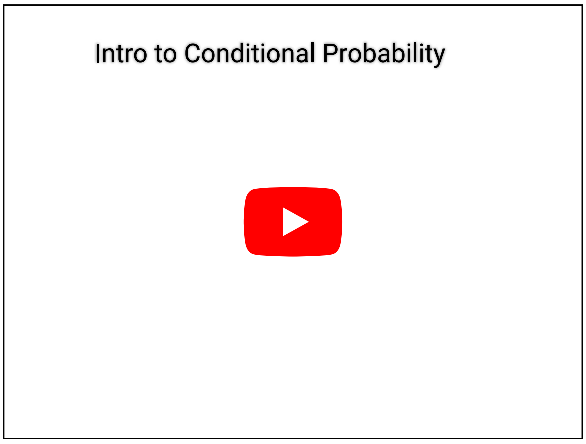
- Chapter 8 – Reasoning under Uncertainty

Mathisfun. (n.d.). *Bayes' Theorem*. https://www.mathsisfun.com/data/bayes-theorem.html

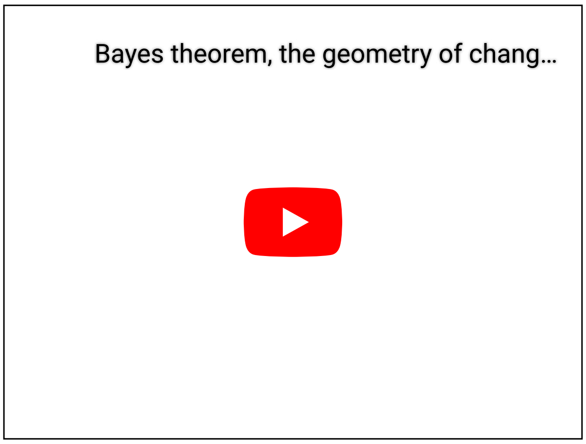
University of the People. (2020). *Unit 6 belief network*. Download the pdf or PowerPoint version to use for the Discussion Assignment.

Video Resources

Bazett, T. (2017, November 18). *Intro to conditional probability* [Video]. YouTube.



3Blue1Brown. (2019, December 22). *Bayes theorem* [Video]. YouTube.



Discussion Assignment

Review the Unit 6 belief network available for download on the Reading Assignment page. The belief network extends the electrical domain to include an overhead projector.

Answer the following questions about how knowledge of the values of some variables would affect the probability of another variable:

1. Can knowledge of the value of Projector_plugged_in affect your belief in the value of Sam_reading_book? Explain your answer.
2. Can knowledge of Screen_lit_up affect your belief in Sam_reading_book? Explain your answer.
3. Can knowledge of Projector_plugged_in affect your belief in Sam_reading_book given that you have observed a value for Screen_lit_up? Explain your answer.
4. Which variables could have their probabilities changed if just Lamp_works was observed?
5. Which variables could have their probabilities changed if just Power_in_prjector was observed?

Your Discussion should be at least 250 words in length, but not more than 750 words. Use APA citations and references for the textbook and any other sources used.

Learning Journal

The Learning Journal is a tool for self-reflection on the learning process. The Learning Journal will be assessed by your instructor as part of your Final Grade.

Your learning journal entry must be a reflective statement that considers the following questions:

1. Describe what you did. This does not mean that you copy and paste from what you have posted or the assignments you have prepared. You need to describe what you did and how you did it.

2. Describe your reactions to what you did.

3. Describe any feedback you received or any specific interactions you had while participating discussion forum, discuss how they were helpful.

4. Describe your feelings and attitudes.

5. Describe what you learned. You can think of one or more topics from your week's lesson and explain your understanding in writings. Feel free to add any diagram or coding example if that helps you explain better.

6. Did you face any challenges while doing the discussion assignment or the Graded quiz? Were you able to solve it by yourself?

The Learning Journal entry should be a minimum of 400 words and not more than 750 words. Use APA citations and references if you use ideas from the readings or other sources.

Self-Quiz

The Self-Quiz gives you an opportunity to self-assess your knowledge of what you have learned so far.

The results of the Self-Quiz do not count towards your final grade, but the quiz is an important part of the University's learning process and it is expected that you will take it to ensure understanding of the materials presented. Reviewing and analyzing your results will help you perform better on future Graded Quizzes and the Final Exam.

Please access the Self-Quiz on the main course homepage; it will be listed inside the Unit.

Graded Quiz

The Graded Quiz will test your knowledge of all the materials learned thus far. The results of the quiz will count towards your final grade.

Please access the Graded Quiz on the main course homepage; it will be listed inside the Unit. After you click on it, the quiz's introduction will inform you of any time or attempt limits in place.

Good luck!

Checklist

- Peer assess Unit 5 Programming Assignment
- Read the Learning Guide and Reading Assignments
- Participate in the Discussion Assignment (post, comment, and rate in the Discussion Forum)
- Complete an entry in the Learning Journal
- Take the Self-Quiz
- Take the Graded Quiz