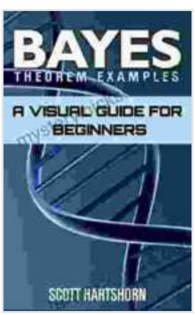
Bayes' Theorem Examples: A Visual Guide for Beginners

Bayes' theorem is a fundamental theorem of probability theory that provides a framework for updating our beliefs in light of new evidence. It is widely used in various fields, including artificial intelligence, machine learning, statistics, and natural language processing. This visual guide aims to provide a comprehensive understanding of Bayes' theorem through real-world examples, making it accessible to beginners.

Bayes' theorem can be expressed as follows:

where:



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- P(AIB) represents the probability of event A occurring given that event B has already occurred. This is known as the posterior probability.

- P(B|A) represents the probability of event B occurring given that event A has already occurred. This is known as the likelihood.
- P(A) represents the prior probability of event A occurring. This is our initial belief about the probability of A before considering any evidence.
- P(B) represents the prior probability of event B occurring. This is the probability of the evidence we observe.

To illustrate Bayes' theorem visually, let's consider a simple example. Suppose we have two urns, Urn A and Urn B. Urn A contains 5 red balls and 3 blue balls, while Urn B contains 2 red balls and 6 blue balls.

We randomly pick an urn and draw a ball. The ball we draw is red. What is the probability that it came from Urn A?

Step 1: Define the events

- A: The ball came from Urn A
- B: The ball is red

Step 2: Calculate the prior probabilities

- P(A) = 0.5 (since there are two urns, and we are equally likely to pick either urn)
- P(B|A) = 5/8 (since there are 5 red balls in Urn A and 8 total balls)
- P(B|¬A) = 2/8 (since there are 2 red balls in Urn B and 8 total balls)

Step 3: Calculate the likelihood

- $P(B|A) = 0.625$ (since $P(B|A) = 5/8$)
- $P(B|\neg A) = 0.25$ (since $P(B|\neg A) = 2/8$)

Step 4: Calculate the posterior probabilities

- Using Bayes' theorem, we can calculate the posterior probabilities:
  - $P(A|B) = (0.625 * 0.5) / (0.625 * 0.5 + 0.25 * 0.5) = 0.714$
  - $P(\neg A|B) = (0.25 * 0.5) / (0.625 * 0.5 + 0.25 * 0.5) = 0.286$

Interpretation

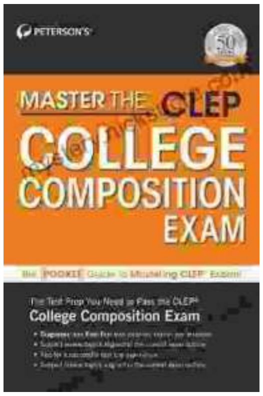
The posterior probability of $P(A|B)$ is 0.714, which means that, given that we drew a red ball, there is a 71.4% chance that it came from Urn A.

- **Medical Diagnosis:** A doctor wants to determine the probability that a patient has a particular disease. The doctor knows that the probability of having the disease is 0.01. The doctor also knows that the probability of a positive test result given that the patient has the disease (sensitivity) is 0.95, and the probability of a positive test result given that the patient does not have the disease (specificity) is 0.99. If the patient tests positive, what is the probability that they actually have the disease?
- **Spam Filtering:** An email filter wants to determine the probability that an email is spam. The filter knows that the probability of an email being spam is 0.05. The filter also knows that the probability of an email being classified as spam given that it is spam (true positive rate) is 0.98, and the probability of an email being classified as spam given

that it is not spam (false positive rate) is 0.02. If an email is classified as spam, what is the probability that it is actually spam?

- **Weather Forecasting:** A meteorologist wants to determine the probability that it will rain tomorrow. The meteorologist knows that the probability of rain is 0.3. The meteorologist also knows that the probability of a weather forecast predicting rain given that it will rain (accuracy) is 0.8, and the probability of a weather forecast predicting rain given that it will not rain (false alarm rate) is 0.2. If the weather forecast predicts rain, what is the probability that it will actually rain?

Bayes' theorem is a powerful tool for updating our beliefs in light of new evidence. By understanding how to apply Bayes' theorem visually, we can reason more effectively and make better decisions in a variety of situations. This guide provides a strong foundation for further exploration of probability and statistics, enabling us to tackle more complex problems with confidence.



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