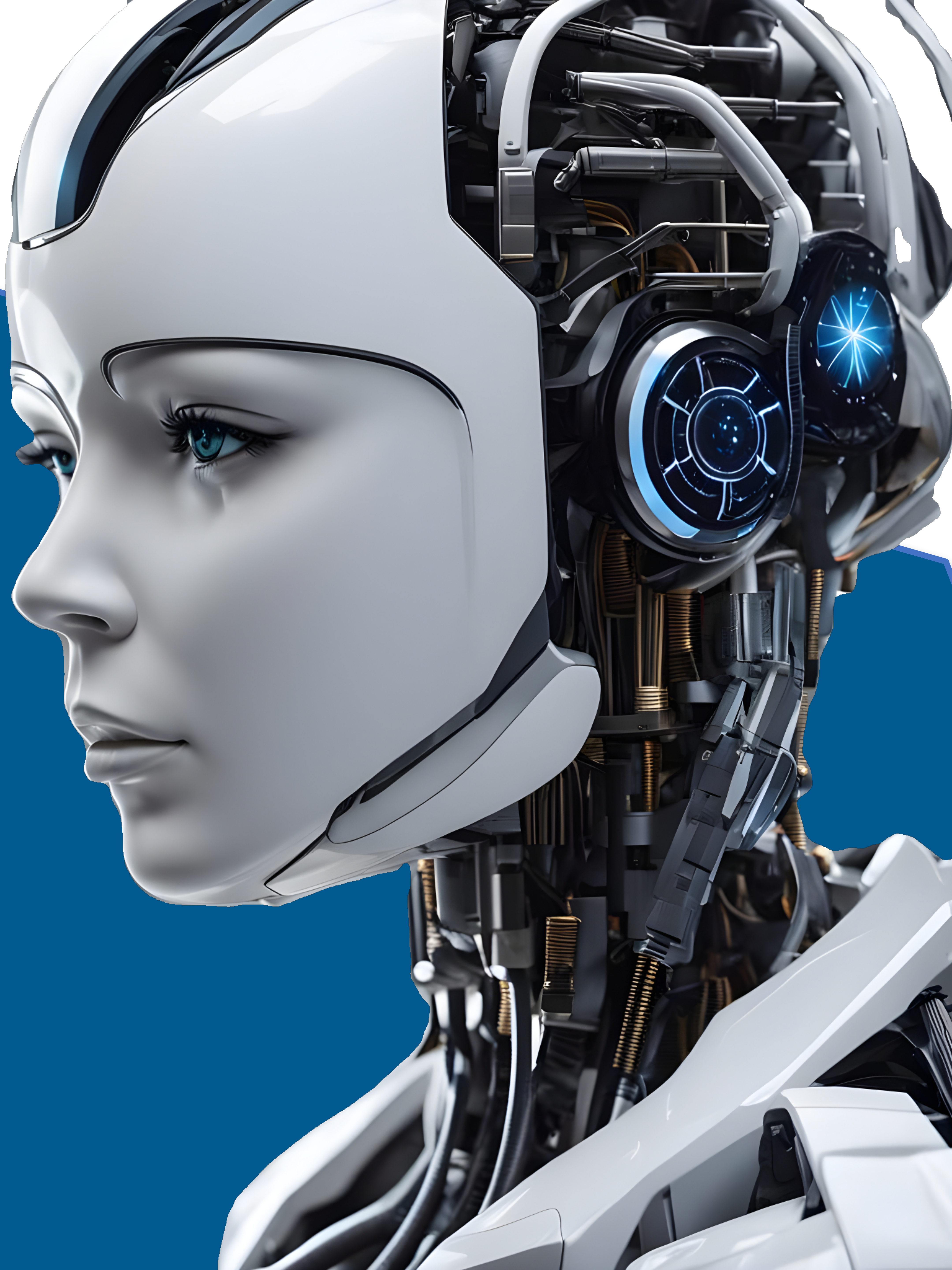
Tishk International University
IT Department
Course Code: IT-344/A

Introduction to Machine Learning

Classifications (Bayes Classifier)

Lecture 5



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Hemin Ibrahim, PhD
hemin.ibrahim@tiu.edu.iq

Outline

- Bayes Classifier
- Bayes' Theorem
- Types of Bayes Classifiers
- Examples

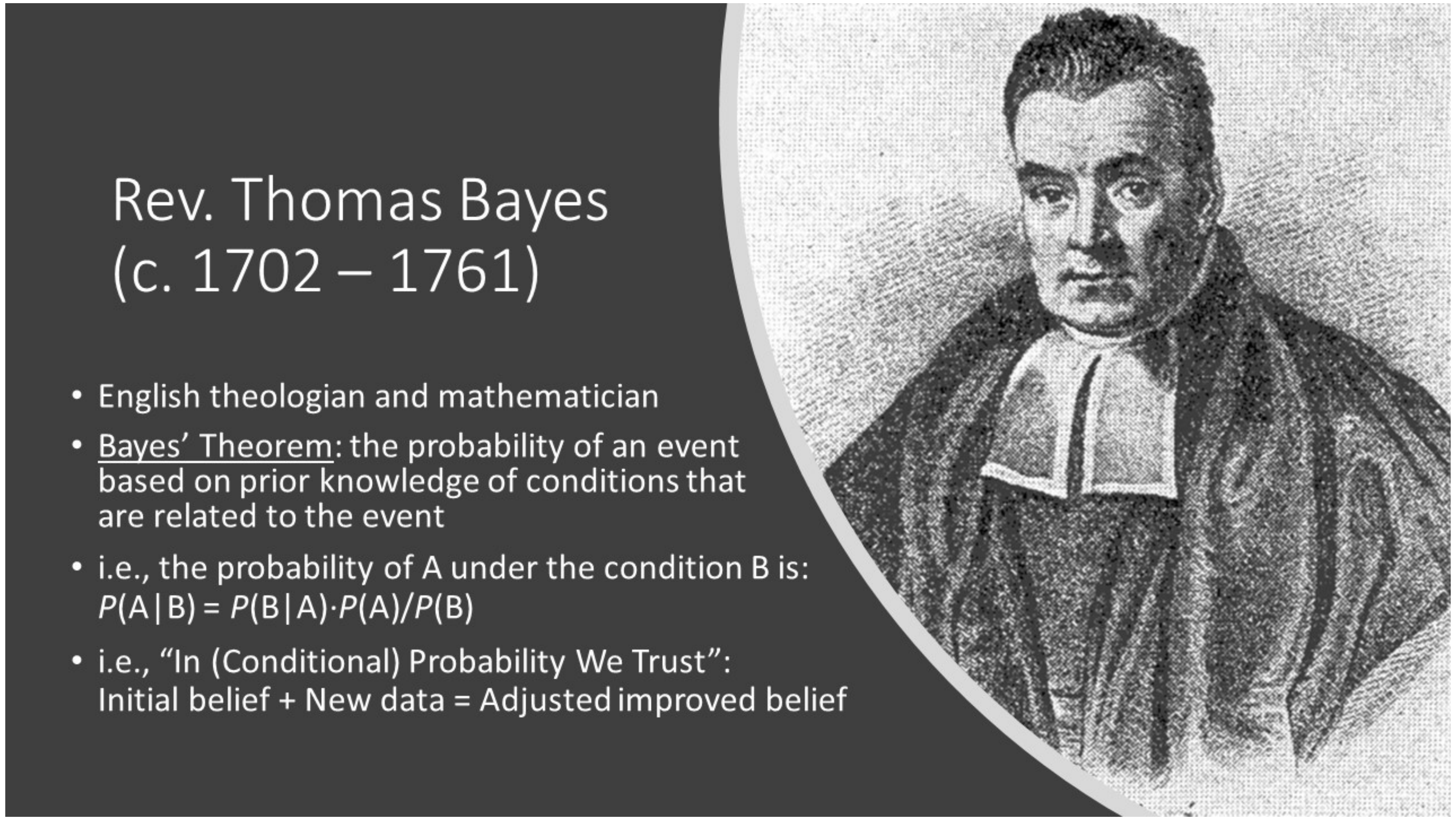
Objectives

- Understand the concept of a Bayes classifier and how it uses Bayes' theorem to classify data based on probability.
- Learn the mathematical formula for Bayes' theorem and how it relates prior and conditional probabilities.
- Analyze real-world examples and use cases where Bayes classifiers are applied, such as spam filtering, sentiment analysis, or document classification

Bayes Classifier

Bayes Classifier is a probabilistic model based on Bayes' theorem used for classification tasks.

- It serves as a foundational concept in probability theory and statistics.
- It calculates the probability of each class given a set of features



Bayes' Theorem

$$P(A|B) = \frac{P(B|A) \cdot P(A)}{P(B)}$$

- $P(A|B)$ is the **posterior** probability of event A given event B has occurred.
- P(B|A) is the **likelihood** of event B occurring given that event A has occurred.
- P(A) is the **prior probability** of event A before considering any new evidence.
- P(B) is the probability of event B occurring, also known as the **marginal likelihood** or **evidence**.

Bayes' Theorem

Likelihood

Prior

Posterior

$$P(A \mid B) = \frac{P(B \mid A) \cdot P(A)}{P(B)}$$

Evidence

- Posterior Probability: Updated probability of classes after considering the evidence.
- Likelihood: Probability of observing data given class.
- Prior Probability: Initial belief about the probability of classes.
- Evidence: Probability of observing the data.

Types of Bayes Classifiers

- **Naive Bayes Classifier**: Assumes independence between features.
- **Gaussian Naive Bayes**: Assumes Gaussian distribution for continuous features.
- **Multinomial Naive Baye**s: Suitable for discrete features with a multinomial distribution.

Example

Normal Message

1. **Hello**, how are you today, **friend**?
2. **Hello** there! Long time no see, **friend**!
3. **Hello**! Would you like to grab food tonight?
4. **Hello friend**, let's catch up over **dinner** soon.
5. **Hello**, it's been a while since we last had dinner together.
6. **Hello friend**, want to join me for **dinner** tomorrow?
7. **Hello friend**, let's plan a **dinner** outing this weekend.
8. **Hello** there, would you like to avail a **discount** on your next time?

8 messages (Normal)	
Word	Count
Hello	8
Friend	5
Dinner	3
Discount	1
Total	17

Example

Spam Messages:

1. **Hello**! Congratulations, you've won a **discount** voucher!
2. Hey there, **friend**! Check out our exclusive **discount** offers!
3. Get ready for amazing **discounts** on our food specials!
4. **Hello**! Don't miss out on our limited-time **discount** deals!

4 messages (Spam)	
Word	Count
Hello	2
Friend	1
Dinner	0
Discount	4
Total	7

Example

8 messages (Normal)		
Word	Count	P(word|N)
Hello	8	p(Hello|N)=8/17=0.47
Friend	5	p(Friend|N)=5/17=0.29
Dinner	3	p(Dinner|N)=3/17=0.18
Discount	1	p(Discount|N)=1/17=0.06
Total	17	

8 messages (Normal)	
Word	Count
Hello	8
Friend	5
Dinner	3
Discount	1
Total	17

p(Normal) = (Normal messages)/(Total messages)

p(N) = 8 / (8 + 4) = 0.67

Example

4 messages (Spam)		
SpamWord	Count	P(SpamWord|S)
Hello	2	P(Hello|S)=2/7=0.29
Friend	1	P(Hello|S)=1/7=0.14
Dinner	0	P(Hello|S)=0/7=0
Discount	4	P(Hello|S)=4/7=0.57
Total	7	

4 messages (Spam)	
Word	Count
Hello	2
Friend	1
Dinner	0
Discount	4
Total	7

p(Spam) = (Spam messages)/(Total messages)

p(S) = 4 / (8 + 4) = 0.33

Example

New Message: **"Hello Friend"**

Normal Class

- **p(Hello|N)=0.47**
- **p(Friend|N)=0.29**
- **p(Dinner|N)=0.18**
- **p(Discount|N)=0.06**
- **p(N) = 0.67**

$$p(\text{N} \mid \text{Hello, Friend}) = p(Hello, Friend \mid N) \times p(N)$$

$$p(\text{N} \mid \text{Hello, Friend}) = p(Hello \mid N) \times p(Friend \mid N) \times p(N)$$

$$p(\text{N} \mid \text{Hello, Friend}) = 0.47 \times 0.29 \times 0.67 \approx 0.09$$

Example

New Message: **"Hello Friend"**

Spam Class

- **p(Hello|S)=0.29**
- **p(Friend|S)=0.14**
- **p(Dinner|S)=0.0**
- **p(Discount|S)=0.57**
- **p(S) = 0.33**

$$p(\text{S} \mid \text{Hello, Friend}) = p(Hello, Friend \mid S) \times p(S)$$

$$p(\text{S} \mid \text{Hello, Friend}) = p(Hello \mid S) \times p(Friend \mid S) \times p(S)$$

$$p(\text{S} \mid \text{Hello, Friend}) = 0.29 \times 0.14 \times 0.33 \approx 0.01$$

Example

$$p(\text{N} \,|\, \text{Hello, Friend}) = 0.47 \times 0.29 \times 0.67 \approx 0.09$$

$$p(\text{S} \,|\, \text{Hello, Friend}) = 0.29 \times 0.14 \times 0.33 \approx 0.01$$

Thus, according to the Bayes classifier, the message "Hello Friend" is more likely to belong to class N (Normal) since the posterior probability for N is higher than that for S.

Exercise

New Message: **"Friend Discount Discount Discount"**

Normal & Spam Class

Hint:

$$p(\text{N} \mid \text{Hello, Friend}) = p(Hello, Friend \mid N) \times p(N)$$

$$p(\text{N} \mid \text{Hello, Friend}) = p(Hello \mid N) \times p(Friend \mid N) \times p(N)$$

$$p(\text{S} \mid \text{Hello, Friend}) = p(Hello, Friend \mid S) \times p(S)$$

$$p(\text{S} \mid \text{Hello, Friend}) = p(Hello \mid S) \times p(Friend \mid S) \times p(S)$$

- **p(Hello|N)=0.47**
- **p(Friend|N)=0.29**
- **p(Dinner|N)=0.18**
- **p(Discount|N)=0.06**
- **p(N) = 0.67**

- **p(Hello|S)=0.29**
- **p(Friend|S)=0.14**
- **p(Dinner|S)=0.0**
- **p(Discount|S)=0.57**
- **p(S) = 0.33**

Exercise

New Message: **"Friend Discount Discount Discount"**

Normal Class

- **p(Hello|N)=0.47**
- **p(Friend|N)=0.29**
- **p(Dinner|N)=0.18**
- **p(Discount|N)=0.06**
- **p(N) = 0.67**

$$p(\text{N} \mid \text{Friend, Discount, Discount, Discount}) = p(Friend, Discount, Discount, Discount \mid N) \times p(N)$$

$$= p(Friend \mid N) \times p(Discount \mid N) \times p(Discount \mid N) \times p(Discount \mid N) \times p(N)$$

$$= 0.29 \times 0.06 \times 0.06 \times 0.06 \times 0.67 \approx 0.000042$$

Exercise

New Message: **"Friend Discount Discount Discount"**

Spam Class

- **p(Hello|S)=0.29**
- **p(Friend|S)=0.14**
- **p(Dinner|S)=0.0**
- **p(Discount|S)=0.57**
- **p(S) = 0.33**

$$p(\text{S} \mid \text{Friend, Discount, Discount, Discount}) = p(Friend, Discount, Discount, Discount \mid S) \times p(S)$$

$$= p(Friend \mid S) \times p(Discount \mid S) \times p(Discount \mid S) \times p(Discount \mid S) \times p(S)$$

$$= 0.14 \times 0.57 \times 0.57 \times 0.57 \times 0.33 \approx 0.0086$$

Exercise

$$p(\text{N} \mid \text{Friend, Discount, Discount, Discount}) = 0.29 \times 0.06 \times 0.06 \times 0.06 \times 0.67 \approx 0.000042$$

$$p(\text{S} \mid \text{Friend, Discount, Discount, Discount}) = 0.14 \times 0.57 \times 0.57 \times 0.57 \times 0.33 \approx 0.0086$$

Thus, according to the Bayes classifier, the message “Friend Discount Discount Discount" is more likely to belong to class S (Spam) since the posterior probability for S is higher than that for N (Normal).

Thank You