

## Introduction to Artificial Intelligence

Unit # 7

Spring 2013

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## Acknowledgement

- The slides of this lecture have been taken from the lecture slides of CS307 – “Introduction to Artificial Intelligence” and CSE652 – “Knowledge Discovery and Data mining” by Dr. Sajjad Haider.

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## Popular Machine Learning Techniques

- Classification
  - Classification Trees ✓
  - **Naïve Bayes**
  - Neural Networks
- Clustering
  - K-Means
  - Associative Memory
- In this course, the focus is on the classification techniques

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## Conditional Probability Example

	B		~B	
	C	~C	C	~C
A	12	5	9	2
~A	4	8	20	4

- $P(A | B, C) = 12/16$
- $P(A, B | \sim C) = 5 / 19$
- $P(B | \sim A, C) = 4 / 24$

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## Conditional Independence

- Two events **A** and **B** are independent if knowing that **A** has happened does not say anything about **B** happening.

$$P(A \cap B) = P(A) P(B)$$

$$P(A | B) = P(A)$$

- Two events **A** and **B** are conditionally independent given a third event **C** precisely if the occurrence or non-occurrence of **A** and **B** are independent events in their conditional probability distribution given **C**.

$$P(A \cap B | C) = P(A | C) P(B | C)$$

$$P(A | B \cap C) = P(A | C)$$

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## Bayes Theorem

- $P(A | B) = \frac{P(B | A) P(A)}{P(B)}$   
 $= \frac{P(B | A) P(A)}{P(B | A) P(A) + P(B | \neg A) P(\neg A)}$
- $P(A)$  is the prior probability and  $P(A | B)$  is the posterior probability.
- Suppose events  $A_1, A_2, \dots, A_k$  are mutually exclusive and exhaustive; i.e., exactly one of the events must occur. Then for any event **B**:

$$P(A_i | B) = \frac{P(B | A_i) P(A_i)}{\sum P(B | A_j) P(A_j)}$$

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## Example I

- According to American Lung Association, 7% of the population has lung cancer. **Of these people having lung disease, 90% are smokers; and of those not having lung disease, 25.3% are smokers.**
- Determine the probability that a randomly selected smoker has lung cancer.

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## Example I Solution

- Let **L** = Lung Cancer, **S** = Smoker
- Given that
  - $P(L) = 0.07$
  - $P(S | L) = 0.90$       $P(\sim S | L) = 0.10$
  - $P(S | \sim L) = 0.253$       $P(\sim S | \sim L) = 0.747$
- Find probability,  $P(L | S)$

$$P(L | S) = \frac{P(S \cap L)}{P(S)} = \frac{P(S | L)P(L)}{P(S | L)P(L) + P(S | \sim L)P(\sim L)}$$

$$P(L | S) = \frac{0.9 \times 0.07}{0.9 \times 0.07 + 0.253 \times 0.93}$$

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## Example II

- Assume that about 1 in 1000 individuals in a given organization have committed a security violation.
- Assume that the **sensitivity** of a routine screening polygraph is about 85%. That is, the probability that the polygraph report will indicate a concern is about 85% if the individual has committed a security violation.
- Assume the **specificity** of the polygraph is about 80%. That is, if the individual has not committed a security violation, there is about an 80% chance that the polygraph report will not indicate a concern.
- What is the posterior probability that an individual whose polygraph report indicates a concern has committed a security violation?

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## Example II Solution

- Let
  - S = Security Violation Committed,
  - T = Test Positive
- Given that
  - P(S) = 0.001
  - P(T | S) = 0.85 P(~T | S) = 0.15
  - P(T | ~S) = 0.20 P(~T | ~S) = 0.80
- Find probability, P(S | T)

$$P(S | T) = \frac{P(T | S)P(S)}{P(T | S)P(S) + P(T | \sim S)P(\sim S)}$$

$$P(T | S) = \frac{0.85 \times 0.001}{0.85 \times 0.001 + 0.20 \times 0.999}$$

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## How to Estimate Probabilities from Data?

Tid	Refund	Marital Status	Taxable Income	Evade
1	Yes	Single	125K	No
2	No	Married	100K	No
3	No	Single	70K	No
4	Yes	Married	120K	No
5	No	Divorced	95K	Yes
6	No	Married	60K	No
7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes

- Class:  $P(C) = N_c / N$

– P(No) = ?  
P(Yes) = ?

- For discrete attributes:

$$P(A_i | C_k) = |A_{ik}| / N_{Ck}$$

– where  $|A_{ik}|$  is number of instances having attribute  $A_i$  and belongs to class  $C_k$

– Examples:

P(Status=Married | No) = ?  
P(Refund=Yes | Yes) = ?

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## How to Estimate Probabilities from Data?

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7	Yes	Divorced	220K	No
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes

- Class:  $P(C) = N_c / N$

– e.g., P(No) = 7/10,  
P(Yes) = 3/10

- For discrete attributes:

$$P(A_i | C_k) = |A_{ik}| / N_{Ck}$$

– where  $|A_{ik}|$  is number of instances having attribute  $A_i$  and belongs to class  $C_k$

– Examples:

P(Status=Married | No) = 4/7  
P(Refund=Yes | Yes) = 0

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## Naïve Bayes

### Classification: Mammals vs. Non-mammals

Name	Give Birth	Can Fly	Live in Water	Have Legs	Class
human	yes	no	no	yes	mammals
python	no	no	no	no	non-mammals
salmon	no	no	yes	no	non-mammals
whale	yes	no	yes	no	mammals
frog	no	no	sometimes	yes	non-mammals
komodo	no	no	no	yes	non-mammals
bat	yes	yes	no	yes	mammals
pigeon	no	yes	no	yes	non-mammals
cat	yes	no	no	yes	mammals
leopard shark	yes	no	yes	no	non-mammals
turtle	no	no	sometimes	yes	non-mammals
penguin	no	no	sometimes	yes	non-mammals
porcupine	yes	no	no	yes	mammals
eel	no	no	yes	no	non-mammals
salamander	no	no	sometimes	yes	non-mammals
gila monster	no	no	no	yes	mammals
platypus	no	no	no	yes	mammals
owl	no	yes	no	yes	non-mammals
dolphin	yes	no	yes	no	mammals
eagle	no	yes	no	yes	non-mammals

- Train the model (learn the parameters) using the given data set.
- Apply the learned model on new cases.

Give Birth	Can Fly	Live in Water	Have Legs	Class
yes	no	yes	no	?

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## Naïve Bayes

### Classification: Mammals vs. Non-mammals

Name	Give Birth	Can Fly	Live in Water	Have Legs	Class
human	yes	no	no	yes	mammals
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salmon	no	no	yes	no	non-mammals
whale	yes	no	yes	no	mammals
frog	no	no	sometimes	yes	non-mammals
komodo	no	no	no	yes	non-mammals
bat	yes	yes	no	yes	mammals
pigeon	no	yes	no	yes	non-mammals
cat	yes	no	no	yes	mammals
leopard shark	yes	no	yes	no	non-mammals
turtle	no	no	sometimes	yes	non-mammals
penguin	no	no	sometimes	yes	non-mammals
porcupine	yes	no	no	yes	mammals
eel	no	no	yes	no	non-mammals
salamander	no	no	sometimes	yes	non-mammals
gila monster	no	no	no	yes	non-mammals
platypus	no	no	no	yes	mammals
owl	no	yes	no	yes	non-mammals
dolphin	yes	no	yes	no	mammals
eagle	no	yes	no	yes	non-mammals

A: attributes

M: mammals

N: non-mammals

$$P(A|M) = \frac{6}{7} \times \frac{6}{7} \times \frac{2}{7} \times \frac{2}{7} = 0.06$$

$$P(A|N) = \frac{1}{13} \times \frac{10}{13} \times \frac{3}{13} \times \frac{4}{13} = 0.0042$$

$$P(A|M)P(M) = 0.06 \times \frac{7}{20} = 0.021$$

$$P(A|N)P(N) = 0.004 \times \frac{13}{20} = 0.0027$$

$P(A|M)P(M) > P(A|N)P(N)$   
=> Mammals

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## Example: Play Tennis

Outlook	Temperature	Humidity	Windy	Class
sunny	hot	high	false	N
sunny	hot	high	true	N
overcast	hot	high	false	P
rain	mild	high	false	P
rain	cool	normal	false	P
rain	cool	normal	true	N
overcast	cool	normal	true	P
sunny	mild	high	false	N
sunny	cool	normal	false	P
rain	mild	normal	false	P
sunny	mild	normal	true	P
overcast	mild	high	true	P
overcast	hot	normal	false	P
rain	mild	high	true	N

$$P(P) = 9/14$$

$$P(N) = 5/14$$

Outlook	Temperature	Humidity	Windy	Class
rain	hot	high	false	?

outlook	
P(sunny p) = 2/9	P(sunny n) = 3/5
P(overcast p) = 4/9	P(overcast n) = 0
P(rain p) = 3/9	P(rain n) = 2/5
temperature	
P(hot p) = 2/9	P(hot n) = 2/5
P(mild p) = 4/9	P(mild n) = 2/5
P(cool p) = 3/9	P(cool n) = 1/5
humidity	
P(high p) = 3/9	P(high n) = 4/5
P(normal p) = 6/9	P(normal n) = 2/5
windy	
P(true p) = 3/9	P(true n) = 3/5
P(false p) = 6/9	P(false n) = 2/5

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