

# Issues with Naïve Bayes Classifier

## Naïve Bayes Classifier:

$$P(\text{Refund} = \text{Yes} \mid \text{No}) = 3/7$$

$$P(\text{Refund} = \text{No} \mid \text{No}) = 4/7$$

$$P(\text{Refund} = \text{Yes} \mid \text{Yes}) = 0$$

$$P(\text{Refund} = \text{No} \mid \text{Yes}) = 1$$

$$P(\text{Marital Status} = \text{Single} \mid \text{No}) = 2/7$$

$$P(\text{Marital Status} = \text{Divorced} \mid \text{No}) = 1/7$$

$$P(\text{Marital Status} = \text{Married} \mid \text{No}) = 4/7$$

$$P(\text{Marital Status} = \text{Single} \mid \text{Yes}) = 2/3$$

$$P(\text{Marital Status} = \text{Divorced} \mid \text{Yes}) = 1/3$$

$$P(\text{Marital Status} = \text{Married} \mid \text{Yes}) = 0$$

For Taxable Income:

If class = No: sample mean = 110

sample variance = 2975

If class = Yes: sample mean = 90

sample variance = 25

- $P(\text{Yes}) = 3/10$

$$P(\text{No}) = 7/10$$

- $P(\text{Yes} \mid \text{Married}) = 0 \times 3/10 / P(\text{Married})$

$$P(\text{No} \mid \text{Married}) = 4/7 \times 7/10 / P(\text{Married})$$

# Issues with Naïve Bayes Classifier

Consider the table with Tid = 7 deleted

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
8	No	Single	85K	Yes
9	No	Married	75K	No
10	No	Single	90K	Yes

**Naïve Bayes Classifier:**

$$P(\text{Refund} = \text{Yes} \mid \text{No}) = 2/6$$

$$P(\text{Refund} = \text{No} \mid \text{No}) = 4/6$$

$$\rightarrow P(\text{Refund} = \text{Yes} \mid \text{Yes}) = 0$$

$$P(\text{Refund} = \text{No} \mid \text{Yes}) = 1$$

$$P(\text{Marital Status} = \text{Single} \mid \text{No}) = 2/6$$

$$\rightarrow P(\text{Marital Status} = \text{Divorced} \mid \text{No}) = 0$$

$$P(\text{Marital Status} = \text{Married} \mid \text{No}) = 4/6$$

$$P(\text{Marital Status} = \text{Single} \mid \text{Yes}) = 2/3$$

$$P(\text{Marital Status} = \text{Divorced} \mid \text{Yes}) = 1/3$$

$$P(\text{Marital Status} = \text{Married} \mid \text{Yes}) = 0/3$$

For Taxable Income:

If class = No: sample mean = 91

sample variance = 685

If class = No: sample mean = 90

sample variance = 25

Given  $X = (\text{Refund} = \text{Yes}, \text{Divorced}, 120K)$

$$P(X \mid \text{No}) = 2/6 \times 0 \times 0.0083 = 0$$

$$P(X \mid \text{Yes}) = 0 \times 1/3 \times 1.2 \times 10^{-9} = 0$$

**Naïve Bayes will not be able to  
classify X as Yes or No!**

# Issues with Naïve Bayes Classifier

- If one of the conditional probabilities is zero, then the entire expression becomes zero
- Need to use other estimates of conditional probabilities than simple fractions

- Probability estimation:

$$\text{Original : } P(A_i | C) = \frac{N_{ic}}{N_c}$$

$$\text{Laplace : } P(A_i | C) = \frac{N_{ic} + 1}{N_c + c}$$

$$\text{m - estimate : } P(A_i | C) = \frac{N_{ic} + mp}{N_c + m}$$

$c$ : number of classes

$p$ : prior probability of the class

$m$ : parameter

$N_c$ : number of instances in the class

$N_{ic}$ : number of instances having attribute value  $A_i$  in class  $c$