## Tut 6: Naive Bayes Classifier

Jan 2022

The general mathematical formulation of a generative model:

$$h_{D}(\boldsymbol{x}) = \underset{j \in \{1, \dots, K\}}{\operatorname{argmax}} \mathbb{P}(Y = j | \boldsymbol{X} = \boldsymbol{x})$$

$$= \underset{j \in \{1, \dots, K\}}{\operatorname{argmax}} \frac{\mathbb{P}(\boldsymbol{X} = \boldsymbol{x} | Y = j) \mathbb{P}(Y = j)}{\mathbb{P}(\boldsymbol{X} = \boldsymbol{x})}$$

$$= \underset{j \in \{1, \dots, K\}}{\operatorname{argmax}} \mathbb{P}(\boldsymbol{X} = \boldsymbol{x} | Y = j) \mathbb{P}(Y = j)$$

$$= \underset{j \in \{1, \dots, K\}}{\operatorname{argmax}} [\ln \mathbb{P}(\boldsymbol{X} = \boldsymbol{x} | Y = j) + \ln \mathbb{P}(Y = j)]$$

$$(6.1)$$

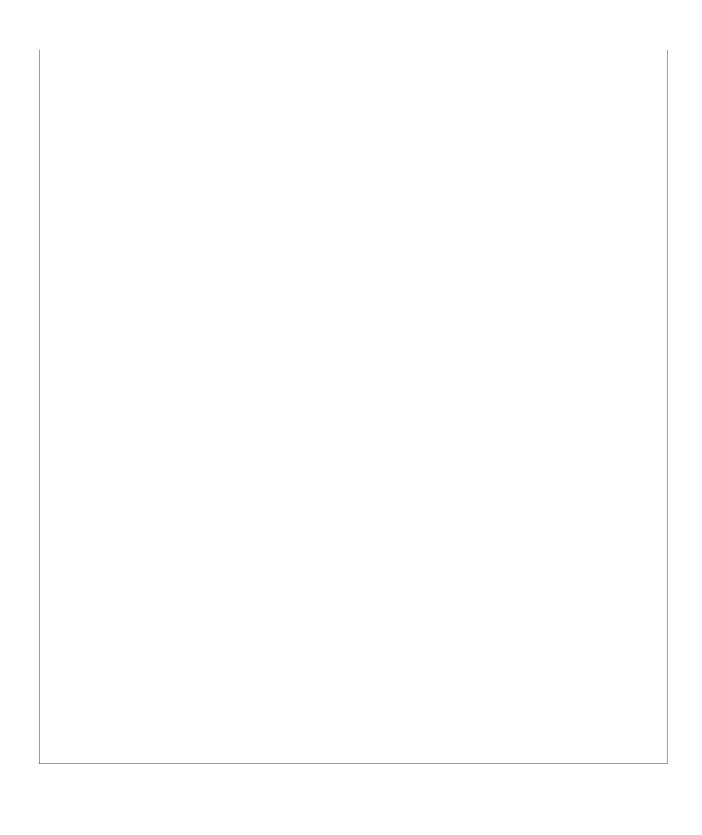
Naive Bayes:

$$\boxed{\mathbb{P}(\boldsymbol{X} = \boldsymbol{x}|Y = j) \approx \prod_{i=1}^{p} \mathbb{P}(X_i = x_i|Y = j)}$$

1. Ahmad would like to construct a model to decide if a day is suitable to play tennis. The table in the next slide shows the results whether to play tennis, based on Outlook, Temperature and Wind, collected by Ahmad.

Using Naïve Bayes approach with Laplace smoothing, predict whether a sunny day with strong wind, 27°C, is suitable to play tennis.

Day	Outlook	Temperature	Wind	PlayTennis
D1	Sunny	34	Weak	No
D2	Sunny	32	Strong	No
D3	Overcast	28	Weak	Yes
D4	Rain	22	Weak	Yes
D5	Rain	16	Weak	Yes
D6	Rain	8	Strong	No
D7	Overcast	12	Strong	Yes
D8	Sunny	20	Weak	No
D9	Sunny	10	Weak	Yes
D10	Rain	23	Weak	Yes
D11	Sunny	19	Strong	Yes
D12	Overcast	21	Strong	Yes
D13	Overcast	31	Weak	Yes
D14	Rain	25	Strong	No



2. The testing dataset of an insurance claim is given in Table 2.1. The variables "gender", "bmi", "age\_bracket" and "previous\_claim" are the predictors and the "claim" is the response.

Table 2.1: The testing data of an insurance claim (randomly sampled with repeated entry).

gender	bmi	age_bracket	previous_claim	claim
female	$under_weight$	18-30	0	$no_{-}claim$
female	$under_{-}weight$	18-30	0	${ m no\_claim}$
$_{\mathrm{male}}$	$over\_weight$	31-50	0	${ m no\_claim}$
female	under_weight	50+	1	$no\_claim$
$_{\mathrm{male}}$	$normal_weight$	18-30	0	$no\_claim$
female	$under\_weight$	18-30	1	$no\_claim$
$_{\mathrm{male}}$	over_weight	18-30	1	$no\_claim$
$_{\mathrm{male}}$	over_weight	50+	1	claim
female	normal_weight	18-30	0	no_claim
female	obese	50+	0	claim

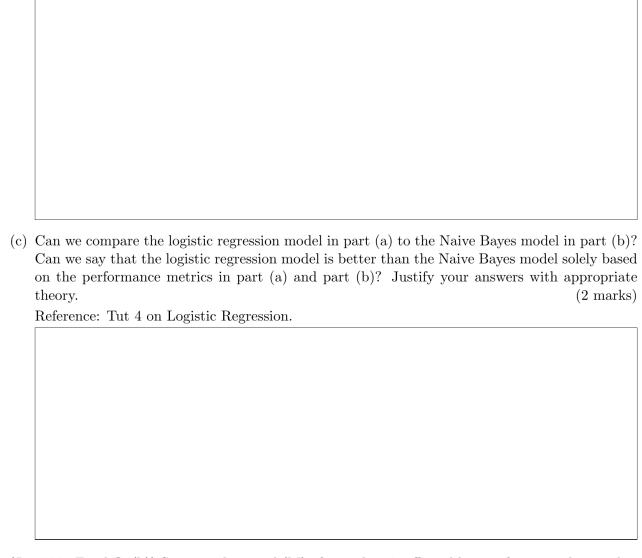
The "gender" is binary categorical data, the "bmi" is a four-value categorical data with values under\_weight, normal\_weight, over\_weight and obese, the "age\_bracket" is a three-value categorical data with value "18-30", "31-50" and "50+", the "previous\_claim" is a binary categorical data with 0 indicating "no previous claim" and 1 indicating "having a previous claim". The "claim" is a binary response with values "no\_claim" (negative class, with value 1) and "claim" (positive class, with value 0).

(b) Write down the mathematical formula for the Naive Bayes model with the predictors and response in Table 2.3. Use the Naive Bayes model trained on the training data from Table 2.3 to **predict** the "claim" of the insurance data in Table 2.1 as well as **evaluating** the performance of the model by calculating the confusion matrix, accuracy, sensitivity, specificity, PPV, NPV of the logistic model.

Table 2.3: The training dataset of an insurance claim data for Naive Bayes model.

Obs.	gender	bmi	$age\_bracket$	$previous\_claim$	$\operatorname{claim}$
1	female	obese	50+	1	no_claim
2	female	under_weight	31-50	0	$no\_claim$
3	male	$under_weight$	31-50	1	${ m no\_claim}$
4	female	over_weight	18-30	1	${ m no\_claim}$
5	female	normal_weight	31-50	0	${ m no\_claim}$
6	female	$under_weight$	31-50	0	$no\_claim$
7	female	obese	18-30	0	$no\_claim$
8	male	$under_weight$	50+	1	$no\_claim$
9	female	$normal_weight$	31-50	0	$no\_claim$
10	male	$over\_weight$	31-50	0	$no\_claim$
11	female	$normal_weight$	50+	0	$\operatorname{claim}$
12	male	$over\_weight$	31-50	1	$\operatorname{claim}$
13	male	underweight	31-50	1	$\operatorname{claim}$
14	male	$over\_weight$	31-50	1	$\operatorname{claim}$
15	male	obese	50+	0	$\operatorname{claim}$
16	male	$under_{-}weight$	50+	0	$\operatorname{claim}$
17	female	obese	31-50	1	$\operatorname{claim}$
18	female	under_weight	50+	1	$\operatorname{claim}$
19	female	normal_weight	50+	1	claim
20	female	under_weight	18-30	1	claim

Note: The default cut-off is 0.5.					



3. (Jan 2021 Final Q4(b)) Suppose the mood (M) of a student is affected by two features, the weather (W) and his result (R) and the Table 4.2.

Table 4.2: Observed Data.

Weather (W)	Result (R)	Mood (M)
Bad	Poor	Unhappy
$\operatorname{Good}$	Poor	Unhappy
$\operatorname{Good}$	Poor	Unhappy
$\operatorname{Good}$	Poor	Unhappy
Bad	Good	Unhappy
Bad	Good	Нарру
Bad	Good	Нарру
$\operatorname{Good}$	Good	Нарру

(a) Using Table 4.2 and a Naive Bayes classifier to predict the mood if today's situation is that the weather is good, the result is good. Show your computations clearly and write down the classifier's prediction. (1.5 marks)

]					
١ ١					
1	Using Table 4.2 and a Naive Baye the weather is bad, the result is pelassifier's prediction.		_	-	
	Suppose an additional feature, ex	ercise (E), w	hich indicates	that the studen	at will carry
	outdoor exercise or not, is added t	to the Table 4	4.2 to form Tab	le 4.3.	V
			ata with New F		
	$\frac{\text{Weather (W)}}{\text{Bad}}$	Result (R) Poor	Exercise (E) No	Mood (M)	
	Good	Poor	Yes	Unhappy Unhappy	
	Good Good Bad Bad Bad Good  Using Table 4.3 and the Naive Bat be performance of the Naive Bayes cl	classifier's p	orediction. Wil	l the new feat	ure impro
	definition that the payer of	assiner moni	the one built b	ased on Table 4	
]	· · · · · · · · · · · · · · · · · · ·				
]	answer.				(2 ma