Data Mining and Machine Learning

Basic methods 1
(1R, Naive Bayes)

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Outline

- [1R](#)
- [Naive Bayes](#)
- [Practice](#)

1R

- a classification algorithm:
  - supervised learning
  - given: set of classified (labelled) data;
  - class attribute: nominal
  - basic version: all attributes are nominal
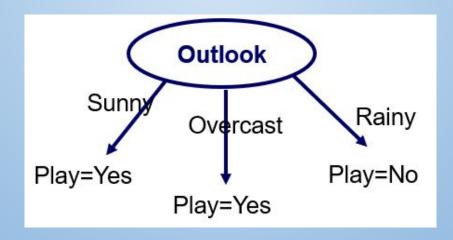 - goal: learn patterns allowing to classify (label) unclassified data

Outlook	Temp.	Humidity	Windy	Play
Sunny	Hot	High	False	No
Sunny	Hot	High	True	No
Overcast	Hot	High	False	Yes
Rainy	Mild	High	False	Yes
Rainy	Cool	Normal	False	Yes
Rainy	Cool	Normal	True	No
Overcast	Cool	Normal	True	Yes
Sunny	Mild	High	False	No
Sunny	Cool	Normal	False	Yes
Rainy	Mild	Normal	False	Yes
Sunny	Mild	Normal	True	Yes
Overcast	Mild	High	True	Yes
Overcast	Hot	Normal	False	Yes
Rainy	Mild	High	True	No

1R

- One Rule: generates a set of rules that all test one particular attribute

Outlook	Temp.	Humidity	Windy	Play
Sunny	Hot	High	False	No
Sunny	Hot	High	True	No
Overcast	Hot	High	False	Yes
Rainy	Mild	High	False	Yes
Rainy	Cool	Normal	False	Yes
Rainy	Cool	Normal	True	No
Overcast	Cool	Normal	True	Yes
Sunny	Mild	High	False	No
Sunny	Cool	Normal	False	Yes
Rainy	Mild	Normal	False	Yes
Sunny	Mild	Normal	True	Yes
Overcast	Mild	High	True	Yes
Overcast	Hot	Normal	False	Yes
Rainy	Mild	High	True	No

IF outlook=sunny THEN play=yes
IF outlook=overcast THEN play=yes
IF outlook=rainy THEN play=no

1R

- 1-level decision tree
- Basic version (assuming nominal attributes)
  - One branch for each of the attribute's values
  - Each branch assigns most frequent class

1R

- Error rate: proportion of instances that don't belong to the majority class of their corresponding branch

- Choose attribute with lowest total error rate

- Calculation: frequency tables

1R - Frequency table

Outlook	Temp.	Humidity	Windy	Play
Sunny	Hot	High	False	No
Sunny	Hot	High	True	No
Overcast	Hot	High	False	Yes
Rainy	Mild	High	False	Yes
Rainy	Cool	Normal	False	Yes
Rainy	Cool	Normal	True	No
Overcast	Cool	Normal	True	Yes
Sunny	Mild	High	False	No
Sunny	Cool	Normal	False	Yes
Rainy	Mild	Normal	False	Yes
Sunny	Mild	Normal	True	Yes
Overcast	Mild	High	True	Yes
Overcast	Hot	Normal	False	Yes
Rainy	Mild	High	True	No

Attribute	Rules	Errors	Total errors
Outlook	Sunny → No	2/5	4/14
	Overcast → Yes	0/4	
	Rainy → Yes	2/5	
Temperature	Hot → No*	2/4	5/14
	Mild → Yes	2/6	
	Cool → Yes	1/4	
Humidity	High → No	3/7	4/14
	Normal → Yes	1/7	
Windy	False → Yes	2/8	5/14
	True → No*	3/6	

Wine dataset

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Wine dataset

- 5 attributes: 4 input + 1 class attribute
  - Alcohol_content: high or low
  - Sweetness: sweet, semi-sweet and dry
  - Type: white, rosé, red
  - (Year: numeric)
  - Popularity: yes / no
- 9 instances

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Attribute	Rules	errors	total errors
Alcohol_content			
Sweetness			
Type			

Attribute	Rules		errors	total errors
Alcohol_content	low	→		
Sweetness				
Type				

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low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Attribute	Rules	errors	total errors
Alcohol_content	low → NO		
Sweetness			
Type			

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low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Attribute	Rules	errors	total errors
Alcohol_content	low → NO	2/5	
Sweetness			
Type			

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low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Attribute	Rules		errors	total errors
Alcohol_content	low	→ NO	2/5	
	high	→		
Sweetness				
Type				

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high	sweet	red	2007	yes
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Sweetness				
Type				

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Attribute	Rules		errors	total errors
Alcohol_content	low	→ NO	2/5	
	high	→ NO (or YES)	2/4	
Sweetness				
Type				

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Sweetness				
Type				

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Attribute	Rules		errors	total errors
Alcohol_content	low	→ NO	2/5	4/9
	high	→ NO (or YES)	2/4	
Sweetness	sweet	→		
Type				

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Attribute	Rules		errors	total errors
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	high	→ NO (or YES)	2/4	
Sweetness	sweet	→ YES		
Type				

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high	sweet	rosé	2013	no
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Attribute	Rules		errors	total errors
Alcohol_content	low	→ NO	2/5	4/9
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Type				

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Alcohol_content	low	→ NO	2/5	4/9
	high	→ NO (or YES)	2/4	
Sweetness	sweet	→ YES	2/4	
	semi-sweet	→ YES	1/2	
Type				

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Sweetness	sweet	→ YES	2/4	
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	dry	→ NO		
Type				

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Type	rosé	→ YES		

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	dry	→ NO	1/3	
Type	rosé	→ YES	1/2	
	red	→ YES	2/5	

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Type	rosé	→ YES	1/2	
	red	→ YES	2/5	
	white	→ NO		

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	dry	→ NO	1/3	
Type	rosé	→ YES	1/2	
	red	→ YES	2/5	
	white	→ NO	0/2	

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	high	→ NO (or YES)	2/4	
Sweetness	sweet	→ YES	2/4	4/9
	semi-sweet	→ YES	1/2	
	dry	→ NO	1/3	
Type	rosé	→ YES	1/2	3/9
	red	→ YES	2/5	
	white	→ NO	0/2	

Selected attribute: Type

Rules:

If Type = rosé   Then Popular = Yes

If Type = red   Then Popular = Yes

If Type = white   Then Popular = No

Decision tree:

Naive Bayes

- Use all attributes

- Assumption: Attributes are *statistically independent* (given the class value)
  - knowledge about the value of a particular attribute doesn't tell us anything about the value of another attribute (if the class is known)

- Classification learning: what's the probability of the class given an instance?

Naive Bayes

- (Relative) frequencies of values in training data

Outlook	Yes	No	Temperature	Yes	No	Humidity	Yes	No	Windy	Yes	No	Play	Yes	No
Sunny	2	3	Hot	2	2	High	3	4	False	6	2		9	5
Overcast	4	0	Mild	4	2	Normal	6	1	True	3	3			
Rainy	3	2	Cool	3	1									
Sunny	2/9	3/5	Hot	2/9	2/5	High	3/9	4/5	False	6/9	2/5		9/14	5/14
Overcast	4/9	0/5	Mild	4/9	2/5	Normal	6/9	1/5	True	3/9	3/5			
Rainy	3/9	2/5	Cool	3/9	1/5									

P(Outlook=Sunny| Play=Yes)

(Outlook: X1, E)

P(Play=Yes)

(Play: Y, class, H)

Wine dataset

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high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Naive Bayes

Alcohol_content	YES	NO	Sweetness	YES	NO	Type	YES	NO	Popular YES	NO
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	YES	NO	Sweetness	YES	NO	Type	YES	NO	Popular YES	NO
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	YES	NO	Sweetness	YES	NO	Type	YES	NO	Popular YES	NO
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low			sweet			rosé				
high			semi-sweet			red			4	
			dry			white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low			sweet			rosé				
high			semi-sweet			red			4	5
			dry			white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content	YES	NO	Sweetness	YES	NO	Type	YES	NO	Popular YES	Popular NO
low	2		sweet			rosé			4	5
high			semi-sweet			red				
			dry			white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet			rosé				
high			semi-sweet			red			4	5
			dry			white				

Alcohol_content			Sweetness			Type				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet			rosé				
high			semi-sweet			red			4	5
			dry			white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet			rosé				
high	2		semi-sweet			red			4	5
			dry			white				

Alcohol_content			Sweetness			Type			Popular	
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet			rosé				
high	2	2	semi-sweet			red			4	5
			dry			white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet			rosé				
high	2	2	semi-sweet			red			4	5
			dry			white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2		rosé				
high	2	2	semi-sweet			red			4	5
			dry			white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé				
high	2	2	semi-sweet			red			4	5
			dry			white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé				
high	2	2	semi-sweet			red			4	5
			dry			white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé				
high	2	2	semi-sweet	1		red			4	5
			dry			white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé				
high	2	2	semi-sweet	1	1	red			4	5
			dry			white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content	YES	NO	Sweetness	YES	NO	Type	YES	NO	Popular YES	Popular NO
low	2	3	sweet	2	2	rosé				
high	2	2	semi-sweet	1	1	red			4	5
			dry			white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé				
high	2	2	semi-sweet	1	1	red			4	5
			dry	1		white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé				
high	2	2	semi-sweet	1	1	red			4	5
			dry	1	2	white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé			4	5
high	2	2	semi-sweet	1	1	red				
			dry	1	2	white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1			
high	2	2	semi-sweet	1	1	red			4	5
			dry	1	2	white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1	1		
high	2	2	semi-sweet	1	1	red			4	5
			dry	1	2	white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1	1		
high	2	2	semi-sweet	1	1	red			4	5
			dry	1	2	white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1	1		
high	2	2	semi-sweet	1	1	red	3		4	5
			dry	1	2	white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1	1		
high	2	2	semi-sweet	1	1	red	3	2	4	5
			dry	1	2	white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1	1		
high	2	2	semi-sweet	1	1	red	3	2	4	5
			dry	1	2	white				
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1	1		
high	2	2	semi-sweet	1	1	red	3	2	4	5
			dry	1	2	white	0			
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1	1		
high	2	2	semi-sweet	1	1	red	3	2	4	5
			dry	1	2	white	0	2		
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content	Sweetness	Type	(Year)	Popular
low	sweet	rosé	2012	yes
low	dry	red	2009	no
low	semi-sweet	red	2008	yes
high	sweet	rosé	2013	no
low	dry	white	2013	no
low	sweet	white	2006	no
high	semi-sweet	red	2011	no
high	sweet	red	2007	yes
high	dry	red	2005	yes

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1	1		
high	2	2	semi-sweet	1	1	red	3	2	4	5
			dry	1	2	white	0	2		
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

If an attribute value doesn't occur with every class value, probability will be zero!

Remedy: add 1 to the count of **every** value-class combination for such problematic attribute (*Laplace estimator)*

Alcohol_content	YES	NO	Sweetness	YES	NO	Type	YES	NO	Popular YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

If an attribute value doesn't occur with every class value, probability will be zero!

Remedy: add 1 to the count of **every** value-class combination for such problematic attribute (*Laplace estimator)*

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low			sweet			rosé				
high			semi-sweet			red				
			dry			white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low			sweet			rosé				
high			semi-sweet			red			4/9	
			dry			white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low			sweet			rosé				
high			semi-sweet			red			4/9	5/9
			dry			white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		

Alcohol_content			Sweetness			Type			Popular	
low			sweet			rosé				
high			semi-sweet			red			4/9	5/9
			dry			white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4		sweet			rosé				
high			semi-sweet			red			4/9	5/9
			dry			white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4		sweet			rosé				
high	2/4		semi-sweet			red			4/9	5/9
			dry			white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4		sweet			rosé				
high	2/4		semi-sweet			red			4/9	5/9
			dry			white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet			rosé				
high	2/4		semi-sweet			red			4/9	5/9
			dry			white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet			rosé				
high	2/4	2/5	semi-sweet			red			4/9	5/9
			dry			white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet			rosé				
high	2/4	2/5	semi-sweet			red			4/9	5/9
			dry			white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4		rosé				
high	2/4	2/5	semi-sweet			red			4/9	5/9
			dry			white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4		rosé				
high	2/4	2/5	semi-sweet	1/4		red			4/9	5/9
			dry			white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4		rosé				
high	2/4	2/5	semi-sweet	1/4		red			4/9	5/9
			dry	1/4		white				

Alcohol_content	YES	NO	Sweetness	YES	NO	Type	YES	NO	Popular YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4		rosé				
high	2/4	2/5	semi-sweet	1/4		red			4/9	5/9
			dry	1/4		white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé				
high	2/4	2/5	semi-sweet	1/4		red			4/9	5/9
			dry	1/4		white				

Alcohol_content	YES	NO	Sweetness	YES	NO	Type	YES	NO	Popular YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé				
high	2/4	2/5	semi-sweet	1/4	1/5	red			4/9	5/9
			dry	1/4		white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé				
high	2/4	2/5	semi-sweet	1/4	1/5	red			4/9	5/9
			dry	1/4	2/5	white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé				
high	2/4	2/5	semi-sweet	1/4	1/5	red			4/9	5/9
			dry	1/4	2/5	white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		

Alcohol_content			Sweetness			Type			Popular	
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7			
high	2/4	2/5	semi-sweet	1/4	1/5	red			4/9	5/9
			dry	1/4	2/5	white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7			
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7		4/9	5/9
			dry	1/4	2/5	white				

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7			
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7		4/9	5/9
			dry	1/4	2/5	white	1/7			

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7			
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7		4/9	5/9
			dry	1/4	2/5	white	1/7			

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		

Alcohol_content			Sweetness			Type			Popular	
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7		4/9	5/9
			dry	1/4	2/5	white	1/7			

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7			

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

$$\Pr[yes \mid E] = \Pr[Alcohol\_content = Low \mid yes] \times \Pr[Sweetness = dry \mid yes] \times \Pr[Type = rosé \mid yes] \times \frac{\Pr[yes]}{\Pr[E]}$$

$$\Pr[no \mid E] = \Pr[Alcohol\_content = Low \mid no] \times \Pr[Sweetness = dry \mid no] \times \Pr[Type = rosé \mid no] \times \frac{\Pr[no]}{\Pr[E]}$$

Alcohol_content	YES	NO	Sweetness	YES	NO	Type	YES	NO	Popular YES	Popular NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

For **"yes"** =

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		

Alcohol_content			Sweetness			Type			Popular	
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

For **"yes"** = 2/4

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

    For **"yes"** = 2/4 x 1/4

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

For **"yes"** = 2/4 x 1/4 x 2/7

Alcohol_content	YES	NO	Sweetness	YES	NO	Type	YES	NO	Popular	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1			
high	2	2	semi-sweet	1	1	red	3 (4)	2		4	5
			dry	1	2	white	0 (1)	2			
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5			
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5		4/9	5/9
			dry	1/4	2/5	white	1/7	2/5			

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

For **"yes"** = 2/4 x 1/4 x 2/7 x 4/9

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

For **"yes"** = 2/4 x 1/4 x 2/7 x 4/9 = 0.0159

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

For **"yes"** = 2/4 × 1/4 × 2/7 × 4/9 = 0.0159

For "no" = 3/5

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

For **"yes"** = 2/4 × 1/4 × 2/7 × 4/9 = 0.0159

For "no" = 3/5 × 2/5

Alcohol_content	YES	NO	Sweetness	YES	NO	Type	YES	NO	Popular YES	Popular NO
low	2	3	sweet	2	2	rosé	1 (2)	1	4	5
high	2	2	semi-sweet	1	1	red	3 (4)	2		
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5	4/9	5/9
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5		
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

For **"yes"** = 2/4 × 1/4 × 2/7 × 4/9 = 0.0159

For "no" = 3/5 × 2/5 × 1/5

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

For **"yes"** = 2/4 × 1/4 × 2/7 × 4/9 = 0.0159

For "no" = 3/5 × 2/5 × 1/5 × 5/9

Alcohol_content	YES	NO	Sweetness	YES	NO	Type	YES	NO	Popular YES	Popular NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

For **"yes"** = 2/4 × 1/4 × 2/7 × 4/9 = 0.0159

For "no" = 3/5 × 2/5 × 1/5 × 5/9 = 0.0267

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

For **"yes"** = 2/4 × 1/4 × 2/7 × 4/9 = 0.0159

For "no" = 3/5 × 2/5 × 1/5 × 5/9 = 0.0267

Conversion into a probability by normalization:

P("yes") = 0.0159/ (0.0159 + 0.0267) = 0.373

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

For **"yes"** = 2/4 × 1/4 × 2/7 × 4/9 = 0.0159

For "no" = 3/5 × 2/5 × 1/5 × 5/9 = 0.0267

Conversion into a probability by normalization:

P("yes") = 0.0159 / (0.0159 + 0.0267) = 0.373

P("no") = 0.0267 / (0.0159 + 0.0267) = 0.627

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	?

Likelihood of the two classes

For **"yes"** = 2/4 × 1/4 × 2/7 × 4/9 = 0.0159

For "no" = 3/5 × 2/5 × 1/5 × 5/9 = 0.0267

Conversion into a probability by normalization:

P("yes") = 0.0159 / (0.0159 + 0.0267) = 0.373

P("no") = 0.0267 / (0.0159 + 0.0267) = 0.627

Alcohol_content			Sweetness			Type			Popular	
	YES	NO		YES	NO		YES	NO	YES	NO
low	2	3	sweet	2	2	rosé	1 (2)	1		
high	2	2	semi-sweet	1	1	red	3 (4)	2	4	5
			dry	1	2	white	0 (1)	2		
low	2/4	3/5	sweet	2/4	2/5	rosé	2/7	1/5		
high	2/4	2/5	semi-sweet	1/4	1/5	red	4/7	2/5	4/9	5/9
			dry	1/4	2/5	white	1/7	2/5		

Alcohol_content	Sweetness	Type	Popular
low	dry	rosé	no

Likelihood of the two classes

For **"yes"** = 2/4 × 1/4 × 2/7 × 4/9 = 0.0159

For "no" = 3/5 × 2/5 × 1/5 × 5/9 = 0.0267

Conversion into a probability by normalization:

P("yes") = 0.0159/ (0.0159 + 0.0267) = 0.373

P("no") = 0.0267 / (0.0159 + 0.0267) = 0.627

Practice 1R and Naive Bayes Computer store dataset

AGE	COMPETITION	TYPE	PROFIT
old	Yes	swr	Down
old	No	swr	Down
old	No	hwr	Down
mid	Yes	swr	Down
mid	Yes	hwr	Down
mid	No	hwr	Up
mid	No	swr	Up
new	Yes	swr	Up
new	No	hwr	Up
new	No	swr	Up

Practice 1R and Naive Bayes Computer store dataset

AGE	COMPETITION	TYPE	PROFIT
old	Yes	swr	Down
old	No	swr	Down
old	No	hwr	Down
mid	Yes	swr	Down
mid	Yes	hwr	Down
mid	No	hwr	Up
mid	No	swr	Up
new	Yes	swr	Up
new	No	hwr	Up
new	No	swr	Up

New data #1 (ND1)

AGE	COMPETITION	TYPE	PROFIT
Old	Yes	hwr	?

New data #2 (ND2)

AGE	COMPETITION	TYPE	PROFIT
New	Yes	hwr	?

Attribute	Rules	errors	total errors
AGE			
COMPETITION			
TYPE			

AGE	COMPETITION	TYPE	PROFIT
old	Yes	swr	Down
old	No	swr	Down
old	No	hwr	Down
mid	Yes	swr	Down
mid	Yes	hwr	Down
mid	No	hwr	Up
mid	No	swr	Up
new	Yes	swr	Up
new	No	hwr	Up
new	No	swr	Up

AGE			COMPETITION			TYPE			PROFIT	
	down	up		down	up		down	up	down	up
old			yes			swr				
mid			no			hwr				
new										
old			yes			swr				
mid			no			hwr				
new										

AGE	COMPETITION	TYPE	PROFIT
old	Yes	swr	Down
old	No	swr	Down
old	No	hwr	Down
mid	Yes	swr	Down
mid	Yes	hwr	Down
mid	No	hwr	Up
mid	No	swr	Up
new	Yes	swr	Up
new	No	hwr	Up
new	No	swr	Up