Machine Learning

Naive Bayes Classifier

Naive Bayes Classification

- Will my flight be on time? It is Sunny, Hot, Normal Humidity, and not Windy!
- Data from the last several times we took this flight

OUTLOOK	TEMPERATURE	HUMIDITY	WINDY	Flight On Time
Rainy	Hot	High	0	No
Rainy	Hot	High	1	Yes
Overcast	Hot	High	0	Yes
Sunny	Mild	High	0	No
Sunny	Cool	Normal	0	Yes
Sunny	Cool	Normal	1	No
Overcast	Cool	Normal	1	Yes
Rainy	Mild	High	0	No
Rainy	Cool	Normal	0	Yes
Sunny	Mild	Normal	0	Yes
Rainy	Mild	Normal	1	Yes
Overcast	Mild	High	1	Yes
Overcast	Hot	Normal	0	Yes
Sunny	Mild	High	1	No

Probability Review

- If A is any event, then the complement of A, denoted by $\bar{A}$, is the event that A does not occur.

- The probability of A is represented by P(A), and the probability of its complement P($\bar{A}$) = 1 – P(A).

- Let A and B be any events with probabilities P(A) and P(B).

- If you are told that B has occurred, then the probability of A might change. The new probability of A is called the conditional probability of A given B

Probabilistic Independence

- Probabilistic independence means that knowledge of one event is of no value when assessing the probability of the other.

- The main advantage to knowing that two events are independent is that in that case the multiplication rule simplifies to: P(A and B) = P(A) P(B).

Bayes' Rule

- P(A|B), reads "A given B," represents the probability of A if B was known to have occurred.

- In many situations we would like to understand the relation between P(A|B) and P(B|A).

- You are planning an outdoor event tomorrow. When it actually rains, the weatherman correctly forecasts rain 90% of the time. When it doesn't rain, he incorrectly forecasts rain 10% of the time. Historically it has rained only 5 days each year. Unfortunately, the weatherman has predicted rain for tomorrow. What is the probability that it will rain tomorrow?

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

Bayes' Rule Continued

- Let A_1 through A_n be a set of mutually exclusive outcomes.

- The probabilities of the As are $P(A_1)$ through $P(A_n)$. These are called prior probabilities.

- Because an information outcome might influence our thinking about the probabilities of any Ai, we need to find the conditional probability P(Ai|B) for each outcome Ai. This is called the posterior probability of Ai.

- Using Bayes' Rule:

$$P(A_i|B) = \frac{P(B|A_i)P(A_i)}{P(B|A_1)P(A_1) + \ldots + P(B|A_n)P(A_n)}$$

Bayes' Rule Continued

- In words, Bayes' rule says that the posterior is the likelihood times the prior, divided by a sum of likelihoods times priors.

- The denominator in Bayes' rule is the probability P(B).

$$\boxed{\text{posterior probability} = \frac{\text{conditional probability} \cdot \text{prior probability}}{\text{evidence}}}$$

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

So will our flight be on time?

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Learning for Life

Outlook

	Yes	No	P(yes)	P(no)
Sunny	2	3	2/9	3/5
vercast	4	0	4/9	0/5
Rainy	3	2	3/9	2/5
Total	9	5	100%	100%

Temperature

	Yes	No	P(yes)	P(no)
Hot	2	2	2/9	2/5
Mild	4	2	4/9	2/5
Cool	3	1	3/9	1/5
Total	9	5	100%	100%

Humidity

	Yes	No	P(yes)	P(no)
High	3	4	3/9	4/5
Normal	6	1	6/9	1/5
Total	9	5	100%	100%

Wir

	Yes	No
False	6	2
True	3	3
Total	9	5

Play		P(Yes)/P(No)
Yes	9	9/14
No	5	5/14
Total	14	100%

Humidity

	Yes	No	P(yes)	P(no)
High	3	4	3/9	4/5
ormal	6	1	6/9	1/5
Total	9	5	100%	100%

Wind

	Yes	No	P(yes)	P(no)
False	6	2	6/9	2/5
True	3	3	3/9	3/5
Total	9	5	100%	100%

Play		P(Yes)/P(No)
Yes	9	9/14

Naïve Bayes Classifiers

- Probabilistic models based on Bayes' theorem.

- It is called "naive" due to the assumption that the features in the dataset are mutually independent

- In real world, the independence assumption is often violated, but naïve Bayes classifiers still tend to perform very well

- Idea is to factor all available evidence in form of predictors into the naïve Bayes rule to obtain more accurate probability for class prediction
- It estimates conditional probability which is the probability that something will happen, given that something else has already occurred. For e.g. the given mail is likely a spam given appearance of words such as "prize"

- fBeing relatively robust, easy to implement, fast, and accurate, naive

Bayes classifiers are used in many different fields

Naïve Bayes Classifiers - Pros and Cons

- Advantages

  - Simple, Fast in processing and effective
  - Does well with noisy data and missing data
  - Requires few examples for training (assuming the data set is a true representative of the population)
  - Easy to obtain estimated probability for a prediction

- Dis-advantages

Relies on and often incorrect assumption of independent features

Gaussian Naive Bayes classifier

- When some of our independent variables are continuous we cannot calculate conditional probabilities!

- In Gaussian Naive Bayes, continuous values associated with each feature (or independent variable) are assumed to be distributed according to a Gaussian distribution

- All we would have to do is estimate the mean and standard deviation of the continuous variable.