

Applying Bayes' Theorem in NLP: Sentiment Analysis

Naive Bayes Classification with a Worked Example

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Why Naive Bayes for NLP?

- Simple, efficient probabilistic classifier for text.
- Based on Bayes' Theorem with conditional independence.
- Performs well on small datasets and sparse features.
- Strong baseline for sentiment analysis tasks.
- Useful for modeling student feedback in educational settings.

Bayes' Theorem

$$P(C \mid d) = \frac{P(d \mid C) P(C)}{P(d)}$$

- C : class (Positive, Negative)
- d : document (bag of words)
- Goal: choose class with highest posterior probability.

Naive Independence Assumption

$$P(d \mid C) = \prod_{i=1}^n P(w_i \mid C)$$

- Words assumed conditionally independent.
- Works surprisingly well despite simplification.
- Very fast to train and apply.

Mini Corpus for Sentiment Analysis

- We build a small labeled dataset:

ID	Sentence	Label
D1	I love this movie	pos
D2	This film is excellent and inspiring	pos
D3	What a terrible and boring movie	neg
D4	I hate this film	neg
D5	An excellent and enjoyable movie	pos
D6	This movie is boring and slow	neg

Preprocessing Pipeline

- Lowercasing and tokenization.
- Removing stopwords: {this, is, a, and, what, i}.
- Final tokens:
 - D1: love, movie
 - D2: film, excellent, inspiring
 - D3: terrible, boring, movie
 - D4: hate, film
 - D5: an, excellent, enjoyable, movie
 - D6: movie, boring, slow

Class Priors

- 3 positive documents
- 3 negative documents

$$P(pos) = 0.5 \quad P(neg) = 0.5$$

Word Counts per Class

Positive class tokens (9 total):

- love(1), movie(2), film(1), excellent(2), inspiring(1), an(1), enjoyable(1)

Negative class tokens (8 total):

- terrible(1), boring(2), movie(2), hate(1), film(1), slow(1)

Laplace Smoothing

$$P(w \mid C) = \frac{\text{count}(w, C) + 1}{N_C + |V|}$$

Vocabulary size: $|V| = 11$

Positive denominator: $9 + 11 = 20$ **Negative denominator:** $8 + 11 = 19$

Test Sentence

- Raw: “This movie is excellent and enjoyable”
- After preprocessing: movie, excellent, enjoyable

Likelihoods for Positive Class

$$P(\textit{movie} \mid \textit{pos}) = \frac{3}{20} = 0.15$$

$$P(\textit{excellent} \mid \textit{pos}) = \frac{3}{20} = 0.15$$

$$P(\textit{enjoyable} \mid \textit{pos}) = \frac{2}{20} = 0.10$$

$$\begin{aligned} P(\textit{pos} \mid d) &\propto 0.5 \times 0.15 \times 0.15 \times 0.10 \\ &= 0.001125 \end{aligned}$$

Likelihoods for Negative Class

$$P(movie \mid neg) = \frac{3}{19} = 0.1579$$

$$P(excellent \mid neg) = \frac{1}{19} = 0.0526$$

$$P(enjoyable \mid neg) = \frac{1}{19} = 0.0526$$

$$\begin{aligned} P(neg \mid d) &\propto 0.5 \times 0.1579 \times 0.0526 \times 0.0526 \\ &\approx 0.0002187 \end{aligned}$$

$$P(pos \mid d) = 0.001125 > 0.0002187 = P(neg \mid d)$$

Classification Result

The sentence is predicted as **Positive**.

Key Takeaways

- Naive Bayes uses Bayes' theorem with independence assumption.
- Works well for text classification tasks.
- Simple to compute, even with tiny datasets.
- Strong baseline for sentiment analysis in educational NLP.