Using Naïve Bayes for Classifying Images by Style

Daniel Keren, Yair Koren, Oleg Sergeive, Igor Kleiner, Gregory Glikin

• The goal: to classify images and video according to “style”.

• Test case: given a painting, identify the painter.
Teaching a computer to appreciate art
Project could eventually help distinguish forgeries from masterpieces

By Bryn Nelson
Columnist
MSNBC
updated 4:08 p.m. ET Feb. 25, 2008

Is that a van Gogh?

A mathematical program that began as a lark for an Israeli scientist has become a serious effort to match some of the world’s greatest painters with their masterpieces. If the project pans out, it could help point out poor copies and eventually distinguish forgeries from the real deal.

Daniel Keren, a professor in the Department of Computer Science at the University of Haifa, said he’s been contacted by an Italian collector hoping to validate some of his acquired paintings as well as by aficionados embroiled in a controversy over the legitimacy of artworks allegedly by Dutch master Vincent van Gogh.
Thomas Bayes (1702-1761)

• Bayes’ Theorem:  \[ P(A/B) = \frac{P(B/A)P(A)}{P(B)} \]

• Application in fitting/classifying:  \[ P(M/D) = \frac{P(D/M)P(M)}{P(D)} \]

Where \( M \) is a model or class, and \( D \) is data.
Naïve Bayes Classifier: Classical Application – Text Categorization

- Given a document $D$, use some keywords to classify it by type (Reuters database is a common benchmark – 20 categories of economics-related articles: oil, shipping, corn…).

- First, keywords with the highest *mutual information* are chosen from a training set. Higher order features can also be used (word pairs, order dependence, word collections with a similar meaning, word stems).

- Then, given a new text, it is classified according to the keywords it contains. The classification maximizes an approximation to the probability of a category given the text/keywords.
• For every word \( w \) and category \( C \), define the probabilities

\[
P(w / C) = \frac{|D \in C, w \in D|}{|D \in C|}, \quad P(C) = \frac{|D \in C|}{|D|}, \quad P(w) = \sum_c P(w / C) P(C)
\]

• The mutual information of a word \( w \) and category \( C \) is defined by

\[
MI(w, C) = P(w / C) \ln \left( \frac{P(w / C)}{P(w)} \right)
\]

• A high value means that \( w \) is a good indicator for \( C \).

• For every category, a few words with the highest mutual information are chosen. These form the set of features, \( \{f_1, \ldots, f_n\} \).
Given a document $D$ which includes the features $\{f_{i_1},...,f_{i_k}\}$, and a category $C$, the probability of $D$ belonging to $C$ is approximated by:

$$P(C / D) = \frac{P(D / C)P(C)}{P(D)} \approx P(C) \frac{P(f_{i_1},...,f_{i_k} / C)}{P(f_{i_1},...,f_{i_k})} \approx P(C) \frac{P(f_{i_1} / C) \cdot \ldots \cdot P(f_{i_k} / C)}{P(f_{i_1}) \cdot \ldots \cdot P(f_{i_k})}$$

This “naïve” approximation assumes that the features are uncorrelated.
Image Style Classification

• Documents are image blocks.

• Features are DCT coefficients which exceed a certain threshold. Thus, *documents and features have the same size*. DCT roughly satisfies the independence assumption.

• For each coefficient, the threshold is chosen so as to maximize the mutual information.

• Discrimination between more than two categories is reduced to a “tournament” or “league” scheme.
The Fourier Transform

Jean Baptiste Joseph Fourier
How can we enhance such an image?
Solution: Image Representation as sum of waves
Heuristics

• Consider only blocks with variance above some threshold.
• Consider only blocks in which the probability of the winning artist is at least twice that of the other artist.

Running Time

• Very fast, since coefficients can be computed using convolution.

Dali features

Magritte features
Threshold Mutual information

Painter A

Painter B
Dali

Van-Gogh
• What happens for images which are a convex combination of two painters (e.g. “0.2*Dali+0.8*Van-Gogh”)?

• Relevance – transparencies, reflection (which recently are drawing a great deal of attention in computer vision).

• The algorithm does not behave linearly; “Dali” paintings which are corrupted by a relatively small amount of “Van-Gogh”, are classified by almost the same strength as the uncontaminated paintings (where “strength” is defined as the ratio of Dali vs. Van-Gogh pixels).

![Diagram](attachment:diagram.png)

Classification of \((1−\lambda)\text{Dali} + \lambda\text{Van-Gogh}\)